Popular Astronomy.

Vol. XVII, No. 1. JANUARY 1909. Whole No. 161

DOOLITTLE'S OBSERVATIONS WITH THE WHARTON REFLEX ZENITH TUBE AT PHILADELPHIA.

T. J. J. SEE.

FOR POPULAR ASTRONOMY.

The paper which we review is part I of volume III of the Astronomical Series of the University of Pennsylvania, containing observations made at the Flower Observatory with the Wharton Reflex Zenith Tube from January 9, 1904, to December 3, 1906, by Professor C. L. Doolittle, Director of the Observatory. This paper affords a remarkable example of exact measurements planned and carried out with a comprehensive grasp of the problems under discussion. It is significant in affording a thorough test of the possibilities of a new form of instrument, of which only one previous example was ever constructed, namely, the Reflex Zenith Tube introduced by Airy at the Greenwich Observatory about half a century ago. Airy had devised this form of instrument, and used it for certain purposes; but that recently built at Philadelphia has the advantage of modern experience, and is no doubt as perfect a type of construction as can be devised at the present time. As this form of instrument is but little known, we shall describe it briefly, so as to enable the reader to understand the essential elements of its constitution.

The Reflex Zenith Tube was provided for the Flower Observatory by Dr. Joseph Wharton of Philadelphia, who realized the advantages to be derived from the verification of Doolittle's classic work on the variation of latitude and the constant of aberration, from a new form of instrument admitting of the highest precision in measurement, but, after all, of comparatively inexpensive pattern.

The Wharton Zenith Tube consists of a pillar of cast iron five feet eight inches in height and weighing about four hundred pounds, resting on a central pier. This is the tube which carries an eight inch objective in its upper end, lying in a horizontal position, with the axis vertical; and the theory of the instrument is such that a Mercury Basin is placed within the

base of the pillar, at one half of the focal distance, to reflect the light of a star in the zenith and form an image in the plane of the objective. A two inch opening in the center of the objective is fitted with a small tube to receive the cone of light reflected from the Mercury below, and a diagonal reflector sends the image of the star and of the threads to the ocular. An adjustment of the height of the Mercury Basin makes it possible to focus the stars exactly in the plane of the micrometer threads, in the center of the object glass; and the observations of the stars are taken in two positions, direct and reversed, with micrometer head north and south respectively. Two small telescopes borne upon the revolving head piece of the Zenith Tube and focused upon the wires enable the observer to measure the differential declinations of the stars as they pass the wires; and the observations are taken in a symmetrical manner.

When the micrometer head is towards the south, the star is observed with the west ocular. The level is first read, and as the star passes across the field two bisections are made at the instant of passing threads II and III. The instrument is reversed by turning the revolving part through 180°, and the star is again bisected when passing the same threads, this time in the reverse order, III–II, and the operation is finished by reading the level. In the Wharton instrument the time of passing from wire III in the first position to wire III in the reversed position is 62 seconds, and the stars are usually taken in opposite order on successive evenings. When first made direct, the bisections next day will be reversed and taken on wires V, IV, and IV and V respectively, instead of II, III and III, II. In Doolittle's observations, the zenith stars are arranged in four groups, of eight stars each, with zenith distances never exceeding 12′, and generally very much less. The star places are derived from all existing material, but some were especially observed by Professor R. H. Tucker of Lick Observatory, and by Mr. George A. Hill of the U. S. Naval Observatory at Washington.

The list of latitude stars includes 130 objects, and one very interesting feature of Professor Doolittle's investigation is the parallelism maintained by the work on the zenith telescope with that on the Wharton Reflex Zenith Tube. This exact parallel of the observations on the two instruments renders the work doubly interesting. There are few examples of such independent results carried over a considerable period, and it is difficult to see how the one before us could be much improved

upon, except by increase of experience. The curves found by Professor Doolittle for the variation of latitude at Philadelphia are illustrated by the accompanying plate. The agreemen between the results of the zenith telescope and of the Wharton Reflex Zenith Tube must be considered on the whole remarkably good. Professor Doolittle believes that his experience has enabled him to make slight improvements in the work as he advanced, and we may therefore expect even more exact results from his future observations. He concludes his memoir of 93 pages as follows:

"As a result of this investigation, we conclude that actual deviations from the mean value of the latitude, as shown by the daily means, which are due to causes not connected with the observer or the instrument, are not of frequent occurrence, though they do not appear to be entirely absent.

In the great majority of cases, however, the daily fluctuations seem to be due to causes not external to the immediate environment.

After the completion of this memoir, the method of illuminating the Wharton instrument was changed, with the result that a very decided improvement seems to have taken place in the character of the work. At the present time decisive evidence is not available, but it seems likely that the unsatisfactory character of the R-D correction will practically disappear.

As the work is still going on, and as some time must elapse before anything like a complete discussion of the entire series can be used, it has been thought best to publish this memoir in present form."

The large value of the constant of aberration previously indicated by the zenith telescope is confirmed by the present work with the Wharton Reflex Zenith Tube (20.″51). The probable errors of the observations with the two instruments are found to be:

	1904	1905	1906
	″	″	″
Zenith Telescope	0.152	0.119	0.095
Wharton Instrument	0.140	0.171	0.102

The two instruments, therefore, are capable of the same order of accuracy, and both admit of measurements of the highest precision.

In the introduction to this Memoir, Professor Doolittle states the purpose of the work with the Wharton Reflex Zenith Tube as follows:

"Many years' experience in latitude work with the Zenith Telescope, at this place and at the Sayre Observatory, South Bethlehem, had appeared to show the desirability of carrying

on for at least two or three years a duplicate series of observations at the same place, employing if possible instruments of different construction. It was hoped that in this way some light might be thrown on the cause of certain puzzling anomalies which occasionally appear in the latitude values, and information be furnished as to whether the uniformly large values of the constant of aberration obtained here and at South Bethlehem are genuine. It seems impossible to decide at present whether the closing error in latitude determination by the polygon method is due entirely to the effect of aberration as has been assumed heretofore, or whether other causes contribute to this result. Supposing the latter to be true it is not difficult to suggest various possible sources of error. Among others, actual small changes in the latitude itself, changes of a systematic character in the instrument or in the observer. The suggestion most commonly made and the one which is perhaps the most plausible, ascribes the effects to refraction changes. So far as the aberration is in question this may not unlikely play an important role, as the conditions are certainly different evening and morning, and the effect is likely to be cumulative rather than otherwise. With two instruments of different construction it appears possible to test with some thoroughness certain of these hypotheses. The question as to the genuineness of the large discrepancies which sometimes appear in the latitudes ought at least to be settled."

Again on page 91 he adds:

"One of the chief objects of this investigation has been a comparison of the values obtained by different methods, for the purpose of ascertaining to what extent they confirm each other, and to see if any information could be had in reference to the character of the fluctuations which sometimes appear.

In the work of 1904, where the same instrument was used with the latitude pairs and the zenith stars, we should expect much the same systematic deviations to be present in both series. In the two following years, however, where two instruments are employed, if any agreement is found in this respect it will probably be due to causes other than instrumental.

The general character of the polar movement is shown most clearly by the graphic representation. By reference to the diagram it will be seen that the most important difference which appears is in the amplitude of the curve, this being more pronounced in the results from the Wharton instrument."

Altogether we may fairly regard Doolittle's work on the difficult subjects of the variation of latitude and constant of aberration as the best in our time. It sets an inspiring example of what is possible in an observatory with moderate equipment, but directed by an experieneed and capable astronomer. The large observatories projected of late years in America have tended to convey the impression to the public mind that little is

left for the small observatories to do. Nothing could be further from the truth than such an impression. The unjustifiable character of such a view is fully recognized by professional astronomers the world over. Would Bessel's small observatory at Königsberg in 1838, for example, compare with our great foundations of to-day, or even with the larger observatories of his time? It was equipped principally with a single instrument—the heliometer. And yet was it not reserved for him to detect and establish for the first time the annual parallax of the fixed stars—a problem which had baffled the skill of astronomers since the days of Aristarchus and Archimedes, and on which modern observers prior to Bessel and equipped in some cases with large instruments had labored in vain? Indeed it is recognized today that we cannot materially improve on the work of Bessel, at any observatory either great or small. In the same way it is justifiable to conclude, from the results already achieved, that it will be very difficult for any future investigator to improve appreciably on the work of Doolittle. The standard of his work is of the highest and the arrangement classic. It marks a new epoch in exact measurement with instruments of the best construction but at the same time of moderate cost. Accordingly it is already recognized that the Flower Observatory has sustained the best traditions of American Astronomy, and the continuation of these important investigations reflects the highest honor upon Philadelphia as a growing center of astronomical research.

U. S. Naval Observatory,
Mare Island, California,
October 24, 1908.

ASTRONOMY,—A PLEA FOR A REVIVAL OF INTEREST IN THE SUBJECT.

WILLIAM TYLER OLCOTT.

FOR POPULAR ASTRONOMY.

When we consider the place astronomy once held in importance in the world's affairs, and how the heavens were eagerly scanned in ancient times for signs that affected the destiny of nations; when we realize the astronomical importance of the great pyramids of Egypt, and of many other temples and mausoleums, it seems a remarkable fact that we, who live in

these modern times, have not at least inherited a passing interest in the study of the stars.

At one time in the world's history no event of importance was ever projected without consulting the stars. Horoscopes were cast immediately on the birth of any personage of rank, and individuals in their daily life consulted the astronomers, who were the learned men of the day, before making any radical changes in their lives or affairs.

To-day we find astronomy neglected by the vast majority;—perhaps not so much neglected as ignored. Men seem quite content to remain in utter ignorance of even the simplest facts relative to our solar system, and appear willing to gaze at a splendid star in stupid wonderment, indifferent as to its name, and unacquainted with the time-honored constellation in which it appears.

Aside from a knowledge of "The Dipper," as a portion of the constellation of "Ursa Major" is familiarly called, the heavens, and all the wonders of the firmament, are a closed book to the multitudes. The grand constellations known to the ancients, and the stars they worshipped thousands of years ago, do not claim even a passing notice in these modern times.

Sidereal Astronomy, that uplifting and fascinating study, seems to find no place in this utilitarian age, and yet in the whole curriculum of knowledge there is no course more teeming with real interest and delight than the study of the heavens.

The astronomer in his contemplation of the stars, keeps ever bright a link in the great chain that Time has forged out of the ages. In his work he is in touch with the spirit of remote centuries. The flashing spheres that nightly inspire him with reverence and awe, awakened like emotions in the breasts of Chaldean shepherds and Roman Emperors. The heavenly bodies that fascinate him, were the contemporaries of primeval man. They were beholden by the patriarchs and prophets of Biblical times. They have illumined the camps of Caesar and his victorious legions. They have calmly watched from their distant heights the rise and fall of the great Napoleon. They have guided the early Phoenician navigators in their voyages on unknown seas, and ever befriended the bewildered mariner. From the depths of infinite space, these wondrous stars have sent their silver shafts through the ages to light the world of chaos, and to mingle with the artificial rays of the lights of an advanced civilization.

What is there in all the realm of nature more beautiful, more

sublime, more wondered at by all nations and all classes, by all ages regardless of sex, from remotest times to our present day, than these same stars, these splendid suns that grace the night, from which emanate the glorious light that spans the centuries, and which bear the message that the dead past reveals to an ever living present.

The geologist, the botanist, and the ornithologist, must travel far afield in his quest for features of interest in his respective study. He is limited also to certain seasons when he may pursue his work. The star-lover, on the contrary, may sit at ease wherever he may happen to be, at any season of the year, and behold the wonders of the heavens in an ever-changing panorama of perpetual beauty. His work is ever accessible, save when clouds interfere, and he is limited alone in the extent of his researches by the optical power at his command.

As the geologist delights in the discovery of a new specimen, the botanist in viewing for the first time a rare orchid, so the star gazer derives unending pleasure in locating the constellations celebrated in the annals of ancient nations, in calling by name the splendid suns that pierce with light the darkness of unfathomable space, and in searching the nocturnal skies for the awe-inspiring sights, the most sublime that nature grants to human eyes.

Few realize the wonders that even an opera-glass reveals. Such meagre optical assistance seems puny and insignificant as compared with the infinite depths of inter-stellar space, yet a trial alone suffices to convince one that the glass, in narrowing the field of vision as it does, discloses many wonders that would otherwise be lost to view. I venture to say that not one person in a thousand has ever seen the beautiful double star Epsilon Lyrae, the mysterious nebula in Andromeda, and the wonderful star cluster between Perseus and Cassiopeia, and yet the opera-glass reveals to advantage these wonders, and countless others.

t may be thought by some that the field of Sidereal Astronomy, regarded in the light of a recreation purely, and denuded of all that is theoretical and mathematical, is narrow in its scope as compared with other sciences. This, I think, is an erroneus impression, as there is, apart from a knowledge of the constellations, a vast field of study for the amateur astronomer, as well as a source of continual pleasure, in the observation of variable stars, in the never ending quest for doubles, clusters and nebulae, in watching for the meteor showers, and in locating those wanderers of the night, the planets as they speed

along the earthly way on their periodic zodiacal visitations. And all this pleasure is within every ones' reach. Does it not seem strange then, that more do not join the ranks of those who see in the sublime vision of the firmament a captivating and ennobling study?

Even the most indifferent person is alive to the beauties of the clear night skies in these latitudes, and the individual must be sadly lacking who has not marveled and admired at some period of his life, a splendid planet, a flashing meteor, or other sublime manifestation of nature as revealed in the grand and impressive star array, and I am prone to think that in general there is a sense of regret on the part of many, who at times contemplate some radiant star, that they do not know its name, and the constellation of which it is a part.

It is a notorious fact that the astronomical course in our schools and colleges is unpopular and rarely successful. In some cases, the course has been given up through lack of interest on the part of the students. In many institutions the course in astronomy is not taken seriously. On the part of the general public we find almost profound ignorance of the subject, and a general apathy existing toward it, so that the question may well be asked when we consider the popularity astronomy once enjoyed, and the prime importance of the subject for so many ages, to what may we attribute the waning interest in the subject?

Is it because inherited prejudice against Astrology, and the charlatans who practiced it to the great detriment of mankind, have tainted the study of the stars? And that this prejudice, the outgrowth of the ages, now marks the race, and renders man insensible and inappreciative of the pleasure that a knowledge of Sidereal Astronomy affords?

Partly this I think, and partly the erroneous impression that seems prevalent among the masses, that even the slightest knowledge of astronomy is difficult to attain. This false notion might be accounted for on the ground that a knowledge of the stars is generally confounded with a knowledge of astronomy in its theoretical and mathematical sense.

As a matter of fact, it is comparatively easy to acquire a thorough knowledge of the constellations in a very short time. With no guide save a planisphere, and possibly one of the many excellent works on the subject, any person of average intelligence can familiarize himself with all the constellations visible in these latitudes, in six months' time. He can acquire this knowledge

in a much shorter time if he is willing to extend his time of observation to the early morning hours.

From the very initial steps, keen interest in the subject is awakened, and success is achieved with ease, which can rarely be said of knowledge in its broadest sense. If more people realized these facts I think we should find revived interest in the realm of star lore.

Again, men blindly ignorant of the truth, regard the study of the stars as of no practical value. But why apply this line of reasoning to what may well be considered a delightful recreation? Few realize however that astronomy has been of the greatest utility and service to the sciences of navigation, chronology, geography, and even agriculture, for in ancient times the rising of certain constellations and stars marked the seasons.

Notwithstanding these facts, we find the study of geology, biology, botany, ornithology, and even forestry, making great strides in the direction of popular favor, while astronomy, the science that once outclassed them all in importance and popularity, the stars to which even kings have rendered homage, and nations worshipped, now interests comparatively few.

Aside from the racial prejudice against astronomy which in my opinion exists, though few of us realize it, or are willing to admit it, the writers of the text-books on astronomy, and the teachers of the subject in our schools and colleges, are in a great measure responsible for the prevailing lack of interest in the subject on the part of the student body.

Instead of approaching the subject solely with a view to interest the pupil, the key-note of success in the teaching of any subject, the opening chapters in most of the text-books on astronomy deal with definitions, and the theoretical matter relative to the motion and position of the heavenly bodies.

The professional astronomers, who are for the most part the authors of these text-books, fail to realize that what they may consider trivial, may often times be of chief importance to the beginner. They do not seem to be able to descend to the plane of the novice, and for the most part write over the head of the reader. As a consequence of this fault the student is bored at the start, a state of affairs which is fatal to his further interest or success.

To illustrate, I have in mind a text-book on astronomy, written by one of our most eminent astronomers, a work of some five hundred pages, and prescribed as the text-book in astronomy

at many of our institutions of learning. Toward the last part of the book, one or two pages are devoted to the constellations. A list of them is merely given, and there follows a vague hint as to where they are to be found. No mention is made of the beauties they contain. No plates show the position of the stars that compose them, and the student would be clever indeed who could from this meagre reference acquaint himself with any one of these grand star groups.

Now my point is this: If the opening chapters in this book had been devoted solely to an exhaustive treatment of the constellations, with accompanying plates that would render the position of them evident to the most indifferent reader; if the interesting facts and noteworthy features concerning each constellation had been fully stated at the outset, the reader could not fail to be interested in the subject at once, and this interest would enable him to pursue the study with intelligence and profit.

The instructor should be ever mindful of the self-evident truth that in the realm of instruction, the way of approaching a subject is the fundamental and all-important factor to be considered and that on this point all future interest and success depend.

Again it is the custom in many of our schools and colleges, to teach astronomy much as history, political economy, and the languages are taught. A certain number of pages in the text-book are prescribed for the daily lesson, and the student recites his astronomy in much the same way as he translates his Cicero and Homer. Why does it never seem to occur to the teachers of the subject that the celestial firmament is the only text-book their students should consult, until they are perfectly familiar with all the constellations and the individual stars of note?

More is to be learned by one night of actual observation, than an entire course of class room work. This is so manifestly true, that were it not for the fact that the class room seems to have the preference over the open sky, it would seem absurd to mention it.

In conclusion, I feel confident that were the proper method of instruction pursued, astronomy would be a popular course in our educational institutions, and the students would find in such a course a source of pleasure that would redound to their lasting benefit.

This lack of discernment on the part of the text-book writers and this failure on the part of the teachers of astronomy to realize that they can only hope to awaken interest in the subject by first familiarizing their pupils with the constellations,

through a preliminary course of field-work, is in a great measure responsible for the waning interest in the sublime study of the stars.

Norwich, Conn.

THE WET AND DRY MOON.

ARTHUR K. BARTLETT.

FOR POPULAR ASTRONOMY.

A popular notion prevails that the position of the lunar crescent is purely an accidental circumstance, and that upon its appearance depend changes in the weather which may be foretold with accuracy, but no belief is more absurd on unfounded, and admits of a more easy scientific explanation. At the time of "new" Moon, the cusps or "horns" of the crescent sometimes lie in a line which is nearly perpendicular with the horizon, and at other times in a line nearly parallel with the horizon. In the former case the Moon is commonly described as "wet" Moon, and in the latter case as a "dry" Moon, and owing to the changing position of the crescent seen on the western sky after sunset, such expressions as these are frequently heard. "If the Moon lies so water can not run out, we shall have a drouth;" "A wet Moon is one upon which the Indian can hang his powder horn," etc. Now, it is a fact not generally known that the crescent Moon always appears "upon its back" in spring, near the vernal equinox, and "upon its end" in autumn, near the autumnal equinox, and these positions, which occur regularly each year, may be easily understood by a little consideration after the conditions have once been carefully explained.

The change of direction the Moon's "horns" are turned is caused by the varying position of the Moon, when at her "new", relatively to the Sun and the Earth, and depends upon the difference in declination of the Sun and Moon. If the Moon be further north than the Sun soon after the "new", the sunlight strikes under her and she appears with her "horns" upturned; but if she be further south the light reaches around her disk to the northward, and her "horns" appear nearly vertical, as if the crescent Moon was resting upon one of them. We see the Moon in varying positions on the sky, and at first sight there appears to be no definite relation between her position and the position of her cusps or "horns". In fact, this feature of her

aspect has seemed so changeful and capricious that it has even been regarded as a weather token. But in reality there is a simple relation always fulfilled by the Moon's horns, or points of the crescent. The line joining them is always at right angles or perpendicular to a line drawn from the Sun to the Moon so that the "horns" are always turned directly away from the Sun. The exact position in which they will stand at any time is, therefore, easily predictable, and has nothing whatever to do with the weather.

The appearance of the "new Moon" in November is regarded as an unfailing weather sign by the sailors, especially on the Great Lakes, and they are in the habit of using it as an argument for a mild or cold winter. The tradition of the lakes, which is a stronger law than any enacted by the United States Weather Bureau, says that if the Moon comes at this time "standing up" there will be a pleasant winter. The traditionary old apothegm runs like this: "Stand-up Moon, lay down sailor; lay-down Moon, stand up sailor." This somewhat inelegantly expressed law means more than a city ordinance full of "be it enacted" phrases, and, plainly translated, the old marine phrase means that when the Moon appears in the west "standing up" the sailor can sleep in his bunk with comfort while his boat glides over a placid lake; but if the Moon "lays down", or upon its back, with its "horns" turned upward, the sailor will not only have to stand up, but keep on a continuous jump about the deck, guiding his boat through the rough and disagreeable weather.

As the Moon is always near the ecliptic, the line joining the cusps is always nearly at right angles to the ecliptic; and it follows, of course, that as the angle at which the ecliptic is inclined to the horizon is variable, so the position of the line joining the cusps also varies with respect to the horizon. As respects the gibbous Moon, or Moon more than half full, these variations are not much noticed, but in the case of the "new" or crescent Moon, generally observed quite near the horizon, they are very noteworthy and can hardly fail to attract attention. The line joining the cusps can not be actually upright when the Sun is below the horizon, for the line must always be square to the great circle passing through the Sun and Moon, and of course, when the Moon is above and the Sun below the horizon, this great circle is inclined to the horizon, and a line perpendicular to it is correspondingly inclined from the vertical. Similar considerations will apply to the case of the "old" crescent

Moon before sunrise, soon after the vernal equinox, when the "horns" are turned in the opposite direction.

It will be obvious, from the extreme cases we have described, that the line joining the cusps may have every possible inclination to the horizon, from being nearly vertical to a horizontal position, and even that the northern cusp may be below the southern, according to the season of the year and the Moon's position in her orbit, "so that," as the late Professor Proctor well remarked, "to assert that there will be such and such weather when the line joining the cusps is seen, (for instance) nearly horizontal, the Moon being new, is the same as asserting that there must be such and such weather at the time of the new Moon in February and March, if the Moon is then nearly at her maximum distance from the ecliptic. And so with all such cases. If there were any value at all in such predictions, they would imply the strictly cyclic return of such and such weather."

The tradition that the crescentof the "new" Moon, when nearly horizontal, foretells a "dry month", or when nearly vertical a "wet month", is too absurd to be refuted, as it is without any foundation whatever. Like most other so-called "signs" those who accept them do so from coincidences observed. Cases which prove the "signs" are noted, but those which do not are neglected, and we are convinced only because we wish to be convinced. The nearly horizontal crescent always happens whenever the plane of the Moon's orbit is in such a position as to carry the Moon past her conjunction above the Sun, and the vertical crescent in the opposite case. The changes from one to another are slow and gradual, and there can be nothing in either to affect temperature or moisture—that is, to cause or prevent rain.

A gentleman residing in the northern part of Michigan, who is interested in astronomy, referring to the Moon and the weather, and requesting an explanation of the "wet" and "dry" Moon, in a letter to the writer, says: "If I may hope for a reply, perhaps you will also inform me why the new Moon at times presents the appearance of having her horns upturned, and at others as though resting upon one of them, thus making what is called the wet or dry Moon. This is the only Moon sign that has ever seemed to me at all to be depended upon, but if there is nothing in it, I should like it kicked away." A number of similar inquiries have been addressed to the writer, both verbally and by letter, and they afford a fair illustration of the misapprehension—not to say ignorance—regarding the subject which

prevails throughout the country, even among persons of education and general intelligence upon most branches of learning, except physical science, and especially astronomy, which is sadly neglected in this mercenary age of the world.

Battle Creek, Michigan.

THE FRANK P. BRACKETT OBSERVATORY DEDICATED.

The celebration of the twentieth anniversary of the founding of Pomona College, Claremont, California, was one in which most tangible results were evident for it was the occasion of the dedication of three new buildings in the presence of its body of over five hundred students, and an equal number of alumni, faculty and invited guests from other institutions. Besides the Arthur K. Smiley Dormitory and the Carnegie Library, was the opening of the Frank P. Brackett Observatory, two cuts of which we present.

In connection with the dedication of the observatory an important address was given by Dr. George E. Hale, director of the Mount Wilson Solar Observatory, on the evening of November twentieth. The Science Club of the College, the Southern California Academy of Science, astronomers and physicists in other educational institutions and observatories were the specially invited guests on this occasion. The subject of Dr. Hale's address was "The Relation of Astronomy to other branches of Science as Illustrated by Recent Solar Discoveries." The lecture was illustrated with apparatus showing some of the effects of a magnetic field upon the cathode rays, and with lantern slides made from recent photographs and spectroheliograms taken at the Mount Wilson Solar Observatory. These indicate clearly the vortical nature of sun-spots. They show the presence of magnetic fields in the vortices, accounting for the widened or doubled lines of the spectrum, and tests of polarization reveal phenomena similar to if not indentical with the so-called Zeeman effects. A full account of these important discoveries is soon to be published elsewhere. The address was given in Dr. Hale's characteristically clear, strong style, with rare modesty and true scientific spirit.

On the morning of the twenty-first came the dedication program at the observatory. The first number was the Presentation of the Keys, by the donor, Mr. Llwellyn Bixby, to President Gates, whose reply we print in full.

"On behalf of the Board of Trustees I accept these keys, representing the gift of Mr. Llewellyn Bixby and others to Pomona College.

Throughout these twenty years there have been many different plans for increased astronomical equipment. Good work has been done in this department, in spite of meager facilities, for the spirit of the *teacher* is always and everywhere altogether the chief equipment in any realm.

There is abundant testimony to the fact that in many South American republics their institutions are provided with the finest and richest apparatus in the Physical Sciences whose "professors" however are so incompetent that they only use these instruments for exhibition purposes to their classes; that is, to explain to the students what the instruments are and in a general way what they are used for. The students do not touch these nor even see them used! So we know that better work has been done in astronomy in the last twenty years in this college than in many an institution of learning, immeasurably better equipped than we, in every respect but one: Such have lacked that living piece of apparatus, a man with the soul of a born teacher. It has been a constant experience of the registrars that upper-classmen and women, even some who temperamentally "hate" mathematics in its hard, high levels, would nevertheless, elect astronomy for the sake of being with Professor Brackett.

Now, after the years of patient waiting, through the generosity of one of the professor's own pupils, of the Pomona Class of 1901, good material equipment is added to that fine pedagogical endowment of spirit.

Neither may it be regarded by any as "small", although in mathematical size of rooms, and in size of glass it seem modest; for most of the actual work in astronomy has been done by comparatively small glasses, and to telescopes like this are to be credited many of the richest discoveries,—for here, too, it is often the "man behind the glass" more than the size of the aperture, that determines the result."

The Trustees of Pomona College renew the commission of this department in our curriculum of studies to Professor Frank P. Brackett, with confidence not less than absolute in the efficiency of administration, and the hope that all the years of your teaching may be spent in work in and with this observatory, and may those years be many and heavy laden with the rich rewards of the great calling of "teacher."

Professor Brackett's address upon receiving the keys follows.

"In receiving these keys, the first word to be spoken must be one of profound appreciation of the generosity of the donor, Mr. Llewellyn Bixby, of his loyalty to his Alma Mater and of his intelligent and active interest in the branch of science for which this building stands, a word also acknowledging his hearty coöperation and valuable suggestions in the planning of the buildings. This is not the careless gift of a man of abun-

dant means, but represents real sacrifice on the part of Mr. Bixby and his wife.

He has made no condition to hamper our work or freedom of thought. Two conditions however he did impose: One, requiring that certain instrumental equipment must be provided; the other condition, concerning the name which he insisted must be given to the observatory, is the only point of criticism against the donor. The name given to this observatory, though it should be of great value to its owner, could not be justified here because of any proprietorship nor for any great work or worthiness, but only as the necessary condition to a very desirable gift to this college.

I deem it however a great honor and shall strive to forget the embarrassment which comes with every passing by this inscription plate, and think only of doing work worthy of this honor.

Standing on the threshold of this building, one cannot refrain from a backward look over the twenty years since the college began its work.

They were years of hard, honest toil, though seeming often like the making of bricks without straw, or to change the figure, one is reminded of the manner of building of the beautiful, residential district of Boston Back Bay. Thousands upon thousands of piles were driven deep into the subsoil of the marshes and bay along the Charles River. Upon this foundation of buried and hidden piles stand many of that city's most beautiful and useful buildings. Our work and lives have been much like these piles, deep out of sight. Let us hope that these foundation pillars may prove sound and well driven.

In these twenty years other departments—Chemistry, Physics, and Biology—one by one, have been well equipped. And it was right that they should be established first: right that they should be added no faster than they could be strongly equipped and maintained. It is better for a college to do a limited range of work well than to dabble in a large curriculum of electives.

In all these years the ambition for better things, for more modern methods, has never wavered and faith in the future of this department, as of the college as a whole, has been unshaken. But the observatory is here at last and with it new responsibilities to be bravely faced, or rather, larger opportunities to be eagerly seized for larger, harder, better work.

We are standing, then, at an open door, and the look from this threshold should be a *forward* look.

Other friends have given generously to the equipment of this building. To Miss M. N. Hathaway, already a warm-hearted patron of the college, and to Mr. George H. Bixby, one of its able trustees, we are indebted for a fine new transit and chronograph for the determination of time. Mr. Charles Harwood, also a devoted trustee of the college, Mr. James Mills of Riverside, and Mr. Franklin Cogswell of Pomona, have given toward the coelostat and horizontal telescope, to be used in the

spectrographic study of the Sun. Mr. Llewellyn Bixby had previously given the six-inch objective for the new equatorial. Earlier classes had also contributed in other ways. To Dr. Hale and Dr. Adams of Solar Observatory of Mt. Wilson we owe a large debt of gratitude for their continued interest and willing advice in planning for the building and its equipment, and especially for their inspiration.

This observatory was designed to carry out what it seems to me is the true function of a college teacher. This function is three fold: first, the advancement of knowledge for himslf and for the world; second, the instruction of the student; and third, that which is of greatest importance in college work, the training of the student to see and think for himself and inspiring him with a love for the truth and a courage to devote himself to its advancement.

Many of the larger observatories are devoted entirely to work of research. They are the astronomers' laboratories. And every live teacher would gladly engage in this kind of work. He strives to keep pace with its progress; for his own good and for the good of the college he should have some opportunity for such work himself. But the duties of the class room and committees, his interest in the college at large and perhaps in the community, and his own physical limitations will usually make this a lesser function.

There is a danger of confining the work too much to the second function, that of instruction simply,—to the acquisition of information in a subject so intensely interesting and in which so much has already been learned. It is possible through the wonderful advances of photography and of printing to continue the study of the stars for years and to cover the whole realm of astronomy, and so to vastly broaden the horizon of one's thought and knowledge.

But this can never take the place of the student's own observation of the stars with the telescope, of his own determination of time, latitude and longitude, and of his learning for himself how to look for the answers to those questions which this very method suggests to him. Happy is the teacher who finds in this personal touch with the student the chief joy of his work.

This observatory may never be the laboratory of a great astronomer, but I trust that it may always be a place where student and teacher shall work together in the search for truth, in this, the grandest realm of science, and that in this spirit of truth many may come to a larger and deeper love of God himself, the center and soul of the universe."

The Frank P. Brackett Observatory is built of field stone and is pleasantly located upon a knoll in the park adjoining the college campus. The dome room contains an equatorial with six-inch Clark objective and mounting by Gaertner. Around the dome room and covering the main part of the building is a flat roof or deck-floor, which furnishes a convenient

place for simple observations. Book-cases surround the equatorial pier in the center of the building below, and a large desk stands in a bay window in the south. A broken transit of three-inch objective and eight-inch divided circle, and a chronograph, both made by Gaertner, occupy the west end of the building.

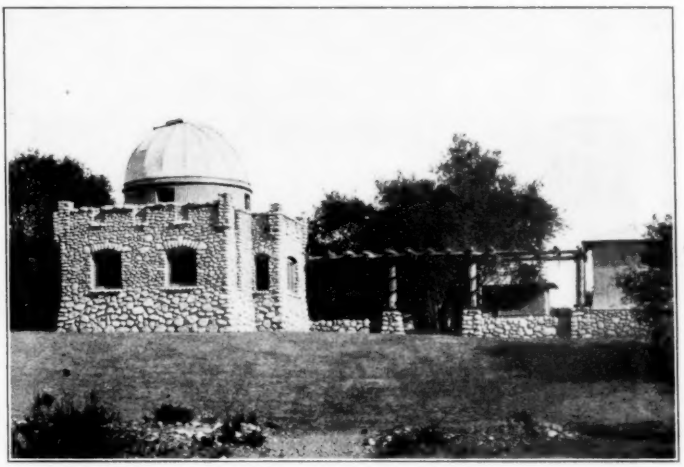
Between this and the main entrance is the clock room with piers for two clocks. Only one of these has been secured. This is a Riefler mean time clock, known as No. 103 Type A. A good laboratory clock will be used for sidereal time until another high grade clock can be provided.

THE FRANK P. BRACKETT OBSERVATORY.

A horizontal telescope and spectrograph for solar study complete the equipment. The optical parts of this instrument are being made by Mr. Petitdidier of Chicago and the coelostat by Mr. Gaertner. The slit and mountings of the telescope and spectrograph were made at home. The coelostat and objective are placed upon concrete piers covered by a small house which is carried on wheels so that it may be rolled off on a track to the south when the instrument is in use. Between this house and the east end of the main building is a pergola, which not only serves an architectural purpose but will, when covered with vines, constitute the tube of the telescope, connecting the objective on its pier next the coelostat with the spectrograph in the "east end." Thus the light from the Sun falls upon the

first mirror of the coelostat, a flat ten inches in diameter, which is driven by clock-work so as to reflect the beam steadily upon a second mirror, a twelve-inch flat, south of the first. From this it is reflected northward through the objective and pergola. This objective has a clear aperture of six and one-fourth inches, and forty feet focal length.

At the focal plane of the objective on a concrete pier is the slit of the spectrograph as well as a plate holder for direct photographs. The spectrograph is of the Littrow type with a



THE FRANK P. BRACKETT OBSERVATORY.

three-inch objective which serves as both collimator and camera lens. It has a focal length of about fifteen feet and is mounted with the grating upon another concrete pier north of the first, the plate-holder and visual eyepiece being placed in the plane of the slit on the middle pier. A small building east of the pergola contains a dark room and toilet conveniences, where all the plumbing is grouped at some distance from the observatory proper.

Astronomy classes numbering nearly fifty, divided into small groups, are already engaged in regular work at the observatory.

PHOTOGRAPHING THE SUN.

DAVID E. HADDEN.

FOR POPULAR ASTRONOMY.

The accompanying photograph of the Sun taken with an ordinary telescope by the writer proved so satisfactory that it was suggested by Professor Payne that I give the readers of POPULAR ASTRONOMY an account of the method used. This I gladly do in the hope that others like myself may be enabled to secure a series of sun-spot photographs for measurements and study without going to the expense of very elaborate or costly apparatus.

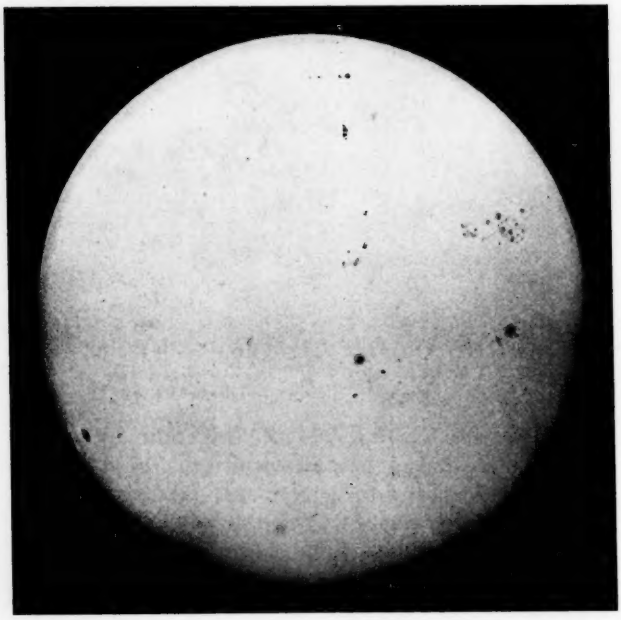


FIGURE 1
Photograph of the Sun taken on September 3d, 1908.

The telescope used has an objective of five and one half inches diameter and solar focus of seventy-five inches, it is equatorially mounted and driven by clockwork. The full aperture is not used but is usually diaphragmed down to a diameter of two to three inches, the smaller size being used in summer when the

altitude of the Sun is greater and the larger when the altitude is lower or the transparency of the atmosphere not good owing to haze, dust or smoke.

After many trials of various enlarging lenses I decided on the achromatic negative system; this I mounted at one end of a piece of brass tube which is attached to the photographic attachment and fits into the eyepiece adapter of the telescope. I am at present using the negative lens of a Bausch & Lomb high power telephoto four by five inch size lens.

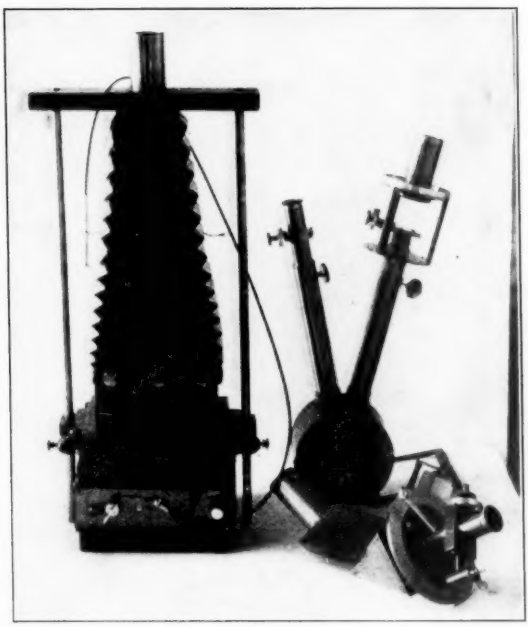


FIGURE 2
Cut shows the solar camera, solar spectroscope and position micrometer fitted to polarizing eyepiece.

The camera attachment as will be observed from the illustration consists of a focal plane four by five inch shutter with dark slide holder and ground glass with long bellows fitted to a strong frame which is firmly fastened to the shutter with brass rods,—the distance of shutter from amplifying lens can be varied so as to vary the diameter of the solar image on the plate; the bellows can be opened or closed without removing

the shutter from the frame so as to permit the use of various yellow ray screens to be slipped on over the amplifying lens tube and inside the bellows. A deep yellow piece of glass has also been let into the bellow's frame quite close to the shutter so as to enable one to see that the solar image is correctly centered on the shutter curtain, which may have been disturbed while inserting plate-holder, and also to watch for moments

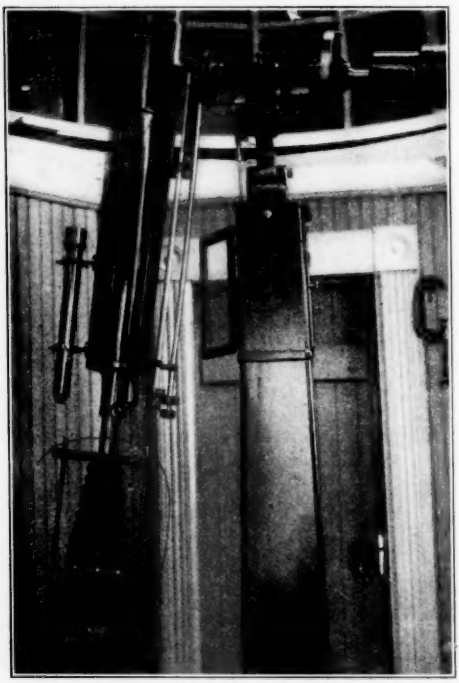


FIGURE 3

Showing the camera attached to the telescope. The black rectangular piece between the bellows and the shutter is the deep yellow glass used to properly center the Sun's image on the shutter curtain and watch for moments of good definition before giving the exposure.

of best definition before giving the exposure; this in no wise admits any amount of harmful light to the plate and greatly facilitates the exposure which can thus be made even without any driving clock.

The focal plane shutter is an ordinary "Graflex" one, having various openings from one eighth inch to one and one half inches

in its curtain, and speeds ranging from "time" to one one-thousandth of a second can be made by adjusting the tension of the spring actuating the curtain, and changing the width of the opening. In practice I have found that the best results are obtained with one eighth inch and three eighths inch openings, corresponding with speeds of one one-thousandth and one three-hundredth of a second, but this depends on the condition of atmosphere and altitude of the Sun.

After many experiments conducted with numerous brands of dry plates I found the Seed's Non-halation Ortho L. plates used in connection with a Seed's Compensator deep yellow ray screen gave the best results. These are developed with a hydrochinon or edinol developer restrained by acetonesulphite and bromide potassium: this usually takes from ten to twenty minutes as the image comes up very slowly, after which it is fixed in an ordinary acid fixing bath.

Figure 3 shows the attachment fitted to the telescope. The following is the modus operandi for obtaining a photograph which does not take more than five minutes in all,—first the telescope is pointed to the Sun and clamped in declination, the camera attachment is then inserted and properly balanced by the counterpoise weights, the image is then accurately focussed on the ground glass by the rack and pinion and oriented by allowing the north or south edge of the Sun or a sun-spot to bisect a parallel line ruled on the ground glass, while the telescope is moved slightly in right ascension; the shutter is then set, the plate holder inserted, slide drawn and exposure made by bulb or spring release.

The resulting pictures are quite satisfactory for obtaining approximate positions and dimensions of sun-spots on a diameter of three to three and one half inches, and when the atmospheric conditions are good, the images are beautifully sharp.

Alta, Iowa.

COLOR-PERCEPTION. II

F. J. B. CORDEIRO.

In this connection it seems to be no chance that the wave-lengths amount to 0,400-750 $\mu\mu$, while the thickness of the large disks measures, according to Max Schultze, about 6 $\mu\mu$. Thus, when waves of a length which is exactly or very nearly the same as the thickness of a disk pass through the same,—

many billions of them in a second—we can easily comprehrend how this coincidence can cause a vibration in the disks. An instructive experiment has already been tried by Oliver Lodge. He let electric wires be in contact with a number of cylinders of different sizes. Then each cylinder sounded with its proper wavelength, and a cylinder which was half the size of another sounded with the octave or the doubled number of vibrations. He called this apparatus the "electric retina", (Lodge, *Modern Views of Electricity*.)

Thus on all sides the opinion is urged that the disks are the light-receiving and refracting parts. Nothing opposes it and many measurements point directly to it. Further, it is possible, with a mechanism like the cones, to explain as a matter of course many phenomena, which were referred to the realm of pure philosophy. The doctrine of complementary colors has been the foundation of many philosophical theories. As is well-known, when all colors are mixed together the perception of white is caused. Sunlight seems white to us because all the disks are set in vibration.

A certain disk responds to a certain period of vibration, yet the others lying nearest to it must share in it to a certain extent. The fundamental color-perception rules, but at the same time the nearest shades enter in. Only by way of exception can we have pure color-perception. The stronger the disturbance the greater becomes the sympathy of the neighboring disks. With a very strong pure color it becomes possible to set the whole row in motion; for this reason a blinding, pure red seems to us to be only white. With moderate vibrations it is possible so to choose two periods that the whole row will be most affected and consequently the perception of whiteness will be more or less perfectly called forth. With three fittingly chosen colors this result is reached still more easily.

When a point in the row of disks is set in motion, there is always a corresponding second point which, working in harmony with the first, influences the whole row more than any other point does. We will indicate such points as complementary. Let us now suppose that a red disk is set in motion, and also a second near to it, then we will perceive a shade between the colors in question. For the second color let us first take a yellow disk; our impressions will now be an orange—an intermediate color, but somewhat mixed with white—no pure color. If we take the second point in blue-green, *i. e.* in the complementary position, then the impression will be moderately white.

Beyond the complementary point, although there is a whitish perception, we can distinguish some red and blue or a whitish purple. Further we see red as such and at the same time violet but weakened by white. These cases are graphically represented in figures 1, 2, 3. It such a mechanical explanation of the

Fig. 1.

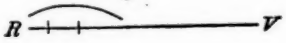


Fig. 2.

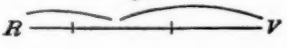


Fig. 3.

complementary colors corresponds to facts, then certain relationships must arise. If, for instance, an end-color is chosen, from which the neighboring vibrations can extend only in one direction, then the complementary point must be situated well beyond the middle in order to be able most advantageously to transmit the vibrations to the whole series. If, one the other hand, the complementary points lie more in the middle then they would be nearer together because the neighboring vibrations would be transmitted on both sides. This is graphically shown in figures 4 and 5.

Fig. 4.

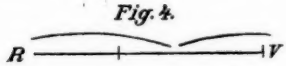


Fig. 5.

In accordance with this, the minimum distance would occur when the corresponding complementary points are equally distant from the ends. The following table from Helmholtz, *Phys. Optik* § 20, shows how the matter stands in this respect.

Color	Wave-length	Complementary-Color	Wave-length	Relationship of the Wave-lengths
Red	6562	Green-blue	492,1	1,334
Orange	607,7	Blue	489,7	1,240
Golden yellow	585,3	Blue	485,4	1,206
Golden yellow	573,9	Blue	482,1	1,190
Yellow	567,1	Indigo-blue	464,5	1,221
Yellow	564,4	Indigo-blue	461,8	1,222
Green-yellow	563,6	Violent	from 433 downward	1,301

Thus our supposition finds here an exact confirmation. As is seen, the minimum of the distance between the complementary points is exactly in the middle of the spectrum. On the other hand this distance becomes a maximum for the end colors.

In the foregoing we have also seen that each cone forms a unit for light and color-perception. From this it follows that each cone must have its own separate connection with the

brain, otherwise a uniform perception could not be traced back to its proper position. Therefore the question forces itself upon us, whether the number of optic fibres actually corresponds to the number of the cones. The answer to this question has already been attempted in several ways and is, of course, somewhat difficult.

The number of cones between certain limits can be reckoned with considerable exactness; but it is quite another matter when the fibres are concerned, as every one knows, who has made an attempt of that sort with a sectional area. We ought not to be surprised that the estimates differ so widely.

Schwalbe says (*Anat. of Organs of Sense* p. 86): "The bundles of nerve fibres consist of fine marrowy nerve-fibres with an average diameter of 2μ. Among them are numerous immeasurably fine ones and occasional thicker ones of $5\text{-}10\mu$ diameter. Therefore the statements of different observers vary within wide limits. Kuhnt finds, surely too low an estimate, about 40,000, Salzner nearly 500,000; Krause, who formerly had estimated the number of nerve-fibres at a million at least, finds recently at least 400,000, stronger and finer fibres besides a number perhaps not less of the smallest ones."

Helmholtz gives the diameter of the marrowless fibres in the papilla at 0,5-3 and 5μ. Let us suppose that the average diameter reaches 1μ, then I have calculated about 1,800,000 fibres; this was done from several sections after deducting the space for the blood-vessels.

Such a calculation, to be sure, leaves much to be desired; but in spite of that we can be moderately certain that the number lies between one and half and two millions, which are wide limits, it is true.

The number of cones can be reckoned more exactly. In the neighborhood of the macula the cones are separated by an average distance of 20μ; in the *ora serrata* there are no cones. Between these two limits the distances regularly increase so that they vary from $\frac{1}{346}$ per μ^2 to 0, according to the distance from the hind eye-pole.

The sum of a magnitude which changes according to a rule can be found only by integral calculus. For this purpose, corrections must be made for two particular places; for the papilla and for the macula where the rule does not apply. In the papilla there are no cones, and in the macula they lie at a distance of $2\text{-}2{,}5\mu$ from one another. Since our readers probably

are not all interested in mathematics, we give only the final result. We find that there are about one and half million in the eye. In different eyes, the numbers may vary somewhat but in all probability they are not very far from the number named. Consequently we have quite a satisfactory agreement between the numbers of the fibres and of the cones. There are fibres enough in the *optikus* to furnish a separate connection with the brain for each cone; perhaps there are even some left over; but not nearly enough for each rod.

It is hard to understand how Salzer reckoned the number of cones at more than three million and the number of optic fibres at only 438,000, which certainly does not accord. Still more incomprehensible is Krause's calculation of seven million cones. In such a case they would have to lie at an average distance of only 12 μ from one another which is clearly impossible.

A few words remain to be said about two other physiological processes. In the darkness the pigment particles of the epithelial layer withdraw from the outer members and leave them quite free. Under the influence of bright light they again come forward and shut off every cone from the one lying next to it. Their function seems to be to limit every local disturbance to to the cone in question and to prevent its being conveyed to the neighboring cone. If the vibrations of a beam are not held fast by their proper cone, then those nearest to it take them up and the phenomenon of irradiation arises. If, e. g., an eye that has been for some time in the darkness suddenly comes into a brightly lighted room one becomes conscious of a feeling of blindness. Distinct sight is impossible on account of irradiation, in spite of the fact that the iris quickly draws itself together and shuts off all peripheral rays. Angelucci found, that in the living retina of animals ten minutes passed after the retreat of the pigment before the outer members became separated from each other again. In the human eye also about that much time is necessary before it can accustom itself to bright light and see comfortably.

It has been observed that under the influence of light the inner members contract and become thicker and shorter. We may perhaps suppose that this has for its purpose the tenser holding of the cones for the sake of a perfect vibration. As is well-known, a loose unattached body does not vibrate. Finally the strongly refracting body with the ellipsoidal surface which is turned toward the light makes the impression of a last refractor.

Conclusions.

In the foregoing investigation the eye is simply considered as an optical instrument and the attempt is made to explain its functions on purely mechanical principles. Everything has directly indicated that the cones are the parts that receive light and dissect colors. We have found in these bodies a construction which is capable of exercising all the mechanical demands of the phenomena that appear. We have met with no contradiction, on the contrary all experiments and measurements have confirmed us in our theory. We have tried to count the cones and optic fibres and have found a probable although not a decisive agreement.

A certain period of vibration influences most strongly the disk with the corresponding vibration period; but when a disturbance is strong enough it can also be transmitted to the neighboring disks. In order to cause a clear perception, there must exist a certain amplitude of vibration. If one blows a weak stream of air into an organ pipe the result is only an uncertain sound; just so, weak light waves give only an indistinct gray spectrum. Too strong a gust of wind in a pipe gives no certain tone, but only a noise; and a pure color, when it is too very brilliant, gives no perception of color but only the sensation of a blinding white. The disturbance has spread itself over the whole series instead of being limited to its corresponding disk.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

For Popular Astronomy.

Part III. (Continued.)

The Nature of the Solar Radiations and their Relation to Terrestrial Magnetism and Other Meteorological Phenomena.

The complete disruption of all the molecules of the gaseous matter at, and near, the solar surface, as aforesaid, constitutes an electric discharge similar to the aurora borealis, and is productive of like electric, magnetic, and luminous effects, while particles of finely divided solid matter are impelled outward by the

dissociated atoms as they fly off in hyperbolic orbits (this process being that known in Chemistry and Physics as Diffusion) and this solid matter being exposed to the superlatively intense thermal radiation near the Sun's surface, is heated to incandescence, its spectrum being therefore continuous, while in a cooler state a little farther away from the solar globe it reflects the sunlight and, therefore, when spectroscopically examined exhibits the Frauenhofer lines of the solar spectrum, the vibrations consequent upon the disruption of the molecules giving the bright lines in the green which are characteristic of the aurora, the lightning flash, and electrical discharges in vacuum tubes.

All readers at all acquainted with the subject of solar physics, will recognize in the theoretical properties of, and action in, the gaseous envelope surrounding the Sun, the well observed phenomena characteristic of that aureole of soft, pearly light which during a total solar eclipse appears encircling the dark disk of the Moon directly intervening between the Earth and the Sun, and which is known as the "corona." The comparatively thin strata of this gaseous matter nearest the Sun's surface, in which all the molecules are completely disrupted by the solar radiation which is superlatively intense in that region, and in which the action is therefore electrical, constitutes what is called the inner corona, and since the number of molecules in unit surface of any layer thereof varies as the inverse square of the distance from the Sun's surface--as measured in radii of the solar globe-there are only one fourth as many affected molecules at a distance of one radius, or about 432,200 miles, as at the surface of the solar globe, and only one molecule out of 46,230 at the surface of the Earth which is roundly 215 solar radii from the center of the Sun, and while in the immediately affected, and completely disrupted molecules directly transmitting the most intense solar radiations, the action is electrical, in contiguous molecules in which there is only partial dissociation of the atomic couples—the molecule itself retaining its general form—the action is magnetic so that the composite total radiation emitted by the Sun through the molecules of the gaseous transmitting medium of luminiferous ether—between the Sun and the Earth and outward to regions far beyond the mean distance of our globe from the center of gravity of the solar system, may be properly regarded as electro-magnetic as first surmised by the late J. Clerk Maxwell, the illustrious English physicist in the latter half of the last century, who regarded light as an electro-magnetic

phenomenon, this view now being held by many physicists, but in so far as I know, there has not been advanced any definite theory as to the specific nature of electricity and magnetism,—particularly in connection with solar physics—such as I have demonstrated as above stated. Since molecules of gaseous matter are disrupted by radiations from a surface heated to an absolute temperature of 6680 degrees Fahrenheit when this matter is at the normal pressure and density of the terrestrial atmosphere, and the effective radiating temperature of the Sun is only 20 or 30 degrees above this, the resultant curves of the orbits of the dissociated atoms are, at the Earth's surface, only a little above the parabolic eccentricity which is 1, these curves being therefore, only slightly hyperbolic, and since the temperature at which the much less rigid molecules of the ether, at a short distance above the solar surface, at the outermost limits of the corona, or about 200,000 miles above said surface, (the extent of the inner corona being only about one twentieth of this) is only 3780 degrees Fahrenheit, the eccentricity of the hyperbolic curves described by the dissociated atoms is so great that their curves approximate very nearly to straight lines and the orbital revolutions of these atoms in outer space are of the nature of longitudinal vibrations analogous to those of the X-rays and others of this general type, whereas when the curves are elliptical—and even not far from parabolic—the maximum amplitude of vibration is in a direction perpendicular to the diameter of each molecule transmitting the radiation, and the vibrations are, therefore, transverse to the rays—these theoretical conclusions being in perfect accordance with well-determined experimental results obtained by the skillful and eminent physicists and with the principles of the undulatory, or wave, theory of light and other forms of radiance.

The undulations set up in the molecules of the ether by the vibrating atoms of the solar radiating matter and which cause complete disruption in some of the affected molecules and, simply, deformations in others, and therefore electro-magnetic effects, whatever light is developed thereby in the matter of the transmitting medium in outer space, when subjected to spectroscopic analysis, should, under my theory, exhibit the three bright lines in the green, at wave lengths 4943, 5031 and 5316 which are well-known spectroscopic characteristics of light consequent upon electric discharges artificially produced as in vacuum tubes and also as exhibited by the lightning flash. Now, all the above described effects are those observed not only in the case of the solar

corona, but also in that of the zodiacal light, that lenticular, luminous apparition which, having its base in the horizon at, and near, the points of sunset and sunrise, has been observed to extend through an elongation of 90 degrees from the Sun, up to the meridian, and even, at times, through a considerably longer arc, which facts indicate that the matter exhibiting these phenomena must extend, from the Sun, to the distance of the Earth and even indefinitely beyond, and all these facts indicate that the zodiacal light is really an extension of the solar corona itself, which is observed to fade gently away in space at a distance of about 200,000 miles from the Sun's surface. As in the case of the solar corona, the dissociated atoms thus impelled outward into space, may carry with them, by impact, portions of finely divided solid matter from the Sun itself, which matter cooled in outer space, must reflect to us, although feebly, the Sun's light incident thereon, and, therefore, give the solar spectrum with its dark Frauenhofer lines as well as the faint electrical spectrum of three bright lines aforesaid, and even were there no solid matter thus driven into outer space, there must, in all probability, exist therein gaseous, and finely divided solid matter, which has been left behind from the primitive solar nebula, as it contracted to the dimensions of the Sun at the present time.

While this electro-magnetic disruptive action in the molecules of the ether thus extends to an indefinitely great distance beyond the Earth, it is obvious that there must be a portion of space, in the form of a cone having, as its base, the diameter of the Earth and its vertex at a distance from 843,300 to 870,300 miles from the center of our globe, within which the molecules of the ether, and whatever other gaseous, or finely divided solid, matter, there may be in outer space, are shielded by the Earth from the above described disruptive action of the solar rays, so that none of the luminous and spectroscopic phenomena exhibited by the zodiacal light is in evidence within this cone, which is identical with the cone of the umbra, or total shadow of the Earth, through a circular section of which the Moon passes eastward in its orbit, more or less directly, on the occasion of each lunar eclipse. If we gaze upward along the axis of this cone, which always extends outward into space in a direction diametrically opposite to that of the Sun, and comes to the meridian at each apparent midnight, throughout the year—since this cone accompanies the Earth, its whole orbital revolution around the Sun—a portion of the disrupted and lum-

inous matter in outer space, at a considerable distance from the Earth, and which is productive of the zodiacal light, must be visible as an approximately circular section through the center whereof passes the axis of the shadow-cone aforesaid, which acts, somewise, as a very long tube or shaft, darkened internally, which excludes all competitive, diffused light in the atmosphere within the cone, and enables the faint luminosity of the zodiacal light within a comparatively small circular area of the sky near the axis of the cone of the shadow, and, therefore, near the opposition to the Sun, to be more distinctly visible than it would otherwise be, the light from this feebly illuminated area, being greatest near the center through which the axis passes and fading away on all sides. The diameter (δ) of this circular illuminated area is given by the equation $\tan \delta = \frac{d'}{x}$; in which the numerator (d') represents the mean diameter of the Earth, and the denominator (x) the distance of the vertex of the shadow cone from the center of our globe, the maximum value of this quantity being 870,300 miles, as above stated, while the value of d' is roundly, 7,900 miles, so that a solution of the equation just set forth gives 0°.5 as the minimum diameter of the very brightest portion or nucleus, the diameter of a section of a cone at one half the aforesaid distance being 1°.0; at one quarter the distance 2°.1; at one eighth, 4°.1, and at one sixteenth, 8°.2, the axis lying nearly in opposition to the Sun and pointing to a declination having the same numerical value, but of opposite sign, as that of that body, and in this connection some highly pertinent and very suggestive facts of observation will now be adduced.

In number 11 of POPULAR ASTRONOMY, (September 1894), there was published a communication from Professor A. E. Douglass, concerning observations of the Gegenschein—or opposition light—that mysterious luminous phenomenon, the specific nature whereof has never been ascertained heretofore, that may be seen in the midnight sky in a position roughly in opposition to the Sun and with opposite declination. From a series of observations of this phenomenon made by himself and another observer, Mr. Ronsie (mostly in Arizona and at Flagstaff in that territory) from March 5 to May 10 in the year 1894, it appears from sixteen observations that the minimum diameter of the approximately circular luminosity aforesaid was 2.5, and the maximum 9.1, the luminosity in the latter case being elongated, in a general direction, eastward and westward. A series of ten

of these observations give from 2.5 to 5.0, and another series from 6.0 to 9.1, the mean of all being 5.4 and deducing the distance (x) of the circular section from the Earth's center, by means of the equation last set forth, I have found it to be 180,500 miles for the minimum diameter (2.5) of the Gegenschein and 49,300 miles for the maximum (9.1), that for the mean (5.4) being, roundly, 83,600 miles. This agreement between observation and my theory, in this connection, leads irresistibly and logically, to the conclusion that the Gegenschein is only a portion of the faint zodiacal light beyond the Earth's orbit, which portion is rendered more conspicuous, visually, by being viewed upward through the Earth's shadow cone aforesaid; that the zodiacal light itself is simply an extension, to an indefinitely great distance outward, of the outer corona of the Sun, and that all these three phenomena are caused principally by the disruptive electrical action in the molecules of the gaseous transmitting medium in space, and, to some extent, by the reflection of sunlight from diffused gaseous and finely divided solid matter in space, and furthermore, that the Aurora Borealis is a result of this same disruptive electrical action, due to the solar rays, among the molecules of the terrestrial atmosphere from its upper limit of 250 miles,—according to my determination—even to the surface of the Earth (on the occasion of great solar outbursts) but in most cases operating in the tenuous atmosphere matter in the upper regions at an average altitude of 20-40 miles from the surface of the Earth—for 28 auroræ Professor H. A. Newton, of Yale College, found heights ranging between 33 miles and 281 miles.

Finally, in this immediate connection, it is most reasonable to conclude that the repellant action of the dissociated atoms of the affected molecules of the gaseous medium in space, being directed outward by the solar radiation, is that which impels in the same direction, the tenuous gaseous and other finely divided matter from the envelope, or coma, of a comet, to form what is called the tail, which is always, in practically all cases, directed away from the Sun, increasing in length, as the comet approaches that body, and shortening as it recedes, the light from these appendages having been observed to give the three characteristic bright lines, in its spectrum as indicative of electrical action as well as those of hydrocarbon vapor and in some cases the faint spectrum of reflected sunlight. Rapid luminous pulsations, due to the dissociation and recombination of the atoms of the disrupted molecules, which constitute electrical

action, have been observed in the tails of comets as well as in the streamers of the Aurora Borealis—a most significant fact in this connection.

It should be remarked that while, under the conditions of my theory, particles of finely divided matter can be, and are, impelled or transmitted from molecule to molecule, to very great distances, by the impacts of the atoms revolving around each molecular center, and by the dissociated atoms of a "couple," in their parabolic, and hyperbolic, flights (this action constituting the well-known physical process called Diffusion) the matter so impelled onward and diffused in space must not be regarded as that by which a quantity of electricity considered as a substance is attached to material particles as a "charge" thereon, a concept, which, although sanctioned by eminent physicists savors too much of the discarded concept of "caloric", in the case of the theory of heat, to be accepted literally, although, like that, it may serve a certain purpose, under a restricted definition. It is a fundamental concept of my theory that, in order to cause electrical action, it is necessary that *motion* only, and not *matter*, be transmitted from molecule to molecule by impacts of the constituent atoms thereof and that the velocity of impact be at, or above, that corresponding to the parabolic limit, the effect being finally developed in the molecules of a single layer of gaseous matter in immediate contact with the surface of a body, such as the Earth, to which the solar radiations are transmitted.

Having in this part of my paper indicated the specific nature of the radiations emitted by the Sun, and which are due primarily to the high temperature of the solar, radiating surface matter the heat whereof has been generated by the compression of the gaseous matter of the primitive solar nebula as it contracted to the present dimensions, of the Sun, in the manner described in the second part of this paper (especially in the February 1908 number of POPULAR ASTRONOMY), the next step in logical sequence is to present a view, under the light of my theory, of the effects of these radiations upon the atoms of the molecules of the gaseous matter that envelops our globe, and is known as the terrestrial atmosphere which consists almost wholly of the simple gases, nitrogen and oxygen, in the volumetric proportion of seventy-nine parts of the former to nearly twenty-one parts of the latter, as a simple *mechanical mixture*, together with a small percentage of carbon dioxide gas and aqueous vapor, the two latter substances, although relatively small in quantity, playing a most important part in

the transformation of the solar electro-magnetic radiations that reach the Earth's surface, and the conservation of the atmospheric heat generated thereby.

It is in the matter of this gaseous envelope that the aforesaid radiations undergo important modifications, and cause therein certain physical phenomena, a determination of the specific nature whereof is most essential to Meteorology which, as a science, is yet in its infancy but rapidly growing, these phenomena being also of the most profound interest to mankind because they immediately concern the physical welfare, and even the very existence, of all forms of living organisms upon the Earth.

Part IV.

The Terrestrial Atmosphere. Its Volume, Extent, Density, Pressure, Temperature and the Meteorological Effects caused therein by the Solar Electro-Magnetic Radiations.

The two principal components of atmospheric air—nitrogen and oxygen—are simple, or perfect, gases, the density of nitrogen being 14.01 (relative to that of hyroden, which is the unit), while the density of oxygen is 15.96, so that, since the relative proportions of these gases in the mechanical mixture constituting atmospheric air are respectively seventy-nine and twenty-one, the mean density of said mixture may be taken as 14.4 and in this respect, it is not necessary to consider these two gases separately.

As I have pointed out, under my theory, the atoms of these gases like the atoms of all other matter—the gaseous luminiferous ether included—are all alike in nature, mass, density and other physical properties, their chemical characteristics resulting simply from the mode of grouping of the atomic orbits in each molecule and the normal orbital velocity of the atoms which are in, the ultimate analysis, the only factors operative in the generation and transmission of radiant energy of all kinds, and since these ultimate particles are all alike, as aforesaid, there need not be any distinction made, in this connection, between the atmospheric gases and the luminiferous ether in outer space. Physicists have generally held that ordinary gaseous, or so-called "gross", matter is incapable of operating in the causation of any of the phenomena of radiation and so far as the *molecules* of such matter are concerned, this view is

correct, these atmospheric molecules, for instance, and the mass composed thereof, transmitting only longitudinal vibrations, such as those of *sound*, but when the almost infinitesimal dimensions and mass of each atom are considered under my theory (each atomic diameter being only $\frac{1}{1273 \times 10^{19}}$ of an inch, or $\frac{1}{5012 \times 10^{18}}$ of a centimeter and the mass of each atom only $\frac{1}{9500 \times 10^{40}}$ of a pound or $\frac{1}{2095 \times 10^{38}}$ of a gram as set forth in my table in the October, 1908, number of POPULAR ASTRONOMY,

I think that these ultimate particles should not be classed as "gross matter" in the ordinary sense, although the density of each atom is superlatively great, being, according to my determination, 3964×10^{22} (density of water = 1) or, roundly, 4×10^{25}, the value in the table on page 500 of the October (1908) number of POPULAR ASTRONOMY having been inadvertently set down as 3964×10^{23}. While nitrogen and oxygen are *chemical elements*, the constitution of their physical molecules, under my theory, would admit of their being broken up, either into separate atoms, or into simple grouping thereof, *chemically inert*, and this possibility seems to be indicated by the derivation of "argon" from atmospheric nitrogen, and the discovery of other chemically inert gases. These separate atoms revolving around the molecular centers, by reason of the deflection due to impacts from a radiating surface, are thrown into elliptic orbits in such wise that there is a *transverse* vibration, or displacement, and also a *longitudinal* stress, the latter increasing with the radiating temperature and becoming predominating, when the parabolic limit has been passed as above described.

Some of the most important and interesting questions of terrestrial physics are those concerning the extent of the Earth's gaseous envelope, and the altitude of the upper limit which defines the extent aforesaid, and the normal density, weight, pressure, temperature, and humidity of the atmosphere, at any altitude above the Earth's surface, relative to the normal values of these quantities at any given point on said surface—as at sea-level in latitude 45°—and for any standard surface temperature—32° Fahr., for instance.

Estimates af the numerical value of each of the quantities aforesaid have been made, in the not distant past, by several eminent physicists, but all such estimates are, admittedly, only approximate—being, in fact, quite widely variant from the true

values—chiefly for the reason that, unless the normal temperature at different altitudes and the mean temperature of the whole gaseous mass be accurately known, the true values aforesaid cannot be obtained, an accurate knowledge of the rate of variation of the temperature with that of the altitude being requisite for the solution of the problem.

Now, the principles, and the mathematical expressions thereof, which I have derived and set forth in a preceding part have enabled me to take into account the effect of temperature and its variation aforesaid, and to determine the upper limit of the atmosphere, which passes through all those points at which the atmospheric pressure and density are just equal to the pressure and density of the interplanetary and interstellar gaseous matter called the "luminiferous ether," and to obtain the numerical values of all the other quantities above mentioned, in a remarkably direct and simple, yet rigorous, manner, and to such a degree of accuracy that the value of the normal atmospheric pressure, which I have computed by means of equations founded upon the principles of my general hypothesis concerning the constitution and functions of gases, differs from the observed value of said pressure, by only one part in nearly 16,380; in other words, the theoretical and the observed or experimental values are *practically identical*,—a fact which, according to a well-known canon of science, certainly constitutes very cogent evidence in favor of said hypothesis; and the course of my investigation upon this subject lies along well-known and established lines of mathematical physics.

A rigorously determined expression of Analytical Mechanics, which shows the relation between the values of the relative atmospheric pressure (P) at different points vertically above any given place on the surface of the Earth and the altitude (h) of any of these points is the following—

$$P = e^{-\frac{h}{x}}, \qquad (1)$$

in which P represents the normal pressure relative to that at the Earth's surface; e, the base of the Napierian system of logarithms, the well-known number 2.718282; and x, the height of the *homogeneous* atmosphere, or, in other words, the height of a column of air when the weight of the purely gaseous matter in the column is exactly equal to the normal pressure of said matter, at the surface of the Earth.

Designating the weight—in pounds avoirdupois—of a cubic foot of dry air at 32° Fahr., and under the normal pressure, by

W, the height (x) of the column aforesaid is, obviously, expressed by the equation—

$$x = 144 \cdot \frac{P_o}{W}, \qquad (2)$$

in which P_o represents the normal surface pressure due to the air column.

The normal pressure of the atmosphere at sea-level and in latitude 45° has been found, by experiment, to be very nearly 14.7302 pounds per square inch; but the atmosphere always contains a considerable quantity of aqueous vapor the tension of which affects the barometric pressure, and the effect of this tension must be eliminated from the observed value of the atmospheric pressure aforesaid, in order to obtain the proper value of P_o to be used in the solution of Equation 2, because in this expression the value of the quantity designated by x is to be regarded as due to the air alone, and the elimination of the effect of aqueous vapor, in this connection, is very easily effected in a well-known manner, as follows:

The experiments of Regnault have demonstrated that the tension of the aequeous vapor contained in a cubic foot of saturated air at the normal temperature and pressure aforesaid, is 0.08916 of a pound per square inch; but the air is not always saturated, nor is it ever entirely destitute of invisible moisture; the "relative humidity" can never exceed 100 and it seldom falls below 15 or 20 per cent; so that 59 per cent is a most probable value for the humidity aforesaid, and, consequently, the tension of the aqueous vapor in air at the normal temperature, pressure and humidity aforesaid is 0.0527 of a pound per square inch; but since the density of said vapor is only .623 that of dry air at the same temperature and pressure, the value of the tension to be deducted from the observed normal barometric pressure of 14.7302 pounds per square inch is .377 that of the tension aforesaid corresponding to 59 per cent of relative humidity, at 32° Fahr., and the value to be thus deducted is, therefore, 0.0199 of a pound, so that the value of P_o to be used in the solution of Equation 2 is 14.7103 of a pound per square inch.

The numerical value of the weight of a cubic foot of dry air, at 32° Fahr. and at normal pressure, has been determined by Regnault and by Lasch, the results obtained by these two physicists closely agreeing, and the mean thereof being 0.0807226 of a pound avoirdupois, which is the value to be substituted

for W in Equation 2, and solving this equation with the values of P and W set forth just above, the value of x is found to be 26,242 feet; converting this into miles, and substituting in Equation 1, we have the following expression for the pressure—

$$\log \frac{1}{P} = 0.087383\ h. \tag{3}$$

The relation between pressure (P) and density (D) is expressed by the equation—

$$P = D^{1.5}, \tag{4}$$

in which the exponent is the *theoretical* ratio between the specific heat of a gas at constant pressure and the specific heat of said gas at constant volume, which I have derived as described in my treatise on the constitution and functions of gases. The experimental value is very nearly 1.41, which is not very different from my theoretical determination; but, although this experimental value has been very accurately determined, its absolute accuracy is, probably, not well established beyond the range of ordinary limited experiments in this connection, while my theoretical value has been rationally derived, and its origin and significance pointed out in the preceding part, and as it leads to more accurate results in its wide application in this investigation than does the experimental value, I have used it in preference to the latter; therefore, reducing Equation 3 by the relation expressed by Equation 4, I have found, as an expression for the density, the following—

$$\log \frac{1}{D} = 0.058255\ h. \tag{5}$$

But these expressions for the pressure and density which I have set forth above are true only on the supposition that the terrestrial force of gravity has the same value at all altitudes above the Earth's surface, which, as is well-known, is not the case, the value varying inversely as the distance from the center of the Earth, and although for small altitudes the effect is ordinarily negligible, it cannot be neglected in this connection.

Saint Paul, Minnesota.

To be continued.

ASTRONOMICAL PHENOMENA IN 1909.

ECLIPSES.

There will be four eclipses during the year 1909, two of the Sun and two of the Moon. The following data are taken from the *American Ephemeris*:

(1) *A Total Eclipse of the Moon*, 1909, June 3 will be visible generally in Europe, Africa and South America. The beginning may be observed also in the southwestern part of Asia. In North America the Moon will rise eclipsed.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of opposition in right ascension, June 3 $13^h\ 19^m\ 7^s.9$

	h	m	s				
Sun's right ascension	4	45	17.68	Hourly motion			10.26
Moon's right ascension	16	45	17.68	Hourly motion			137.03
Sun's declination	+22°	20′	27″.5	Hourly motion	+	0′	18″.3
Moon's declination	−21	58	40 .7	Hourly motion	−	7	5 .6
Sun's equa. hor. parallax			8 .7	Sun's true semidiam.		15	45 .8
Moon's equa. hor. parallax	56	35	.7	Moon's true semidiam.		25	24 .6

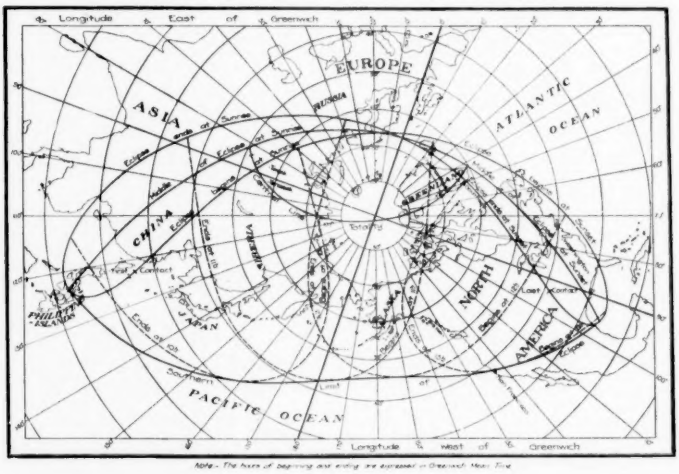
CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time.			Central Standard Time.	
		h	m	h	m
Moon enters penumbra	June 3	10	36.3	4	36.3
Moon enters shadow		11	43.4	5	43.4
Total eclipse begins		12	58.0	6	58.0
Middle of the eclipse		13	28.8	7	28.8
Total eclipse ends		13	59.7	7	59.7
Moon leaves shadow		15	14.3	9	14.3
Moon leaves penumbra		16	21.3	10	21.3

Magnitude of Eclipse = 1.164 (Moon's diameter = 1.0).

(2) *A Central Eclipse of the Sun*, 1909, June 17, will be visible at Washington as a partial eclipse, the Sun setting eclipsed. The central eclipse will begin as an annular eclipse, will change in a few seconds to a total eclipse,

CENTRAL ECLIPSE OF THE SUN JUNE 17TH 1909.



will remain so until within a fraction of a minute of its end, when it will change back to an annular eclipse.

The path of the total eclipse passes almost wholly over the inaccessible regions within the Arctic circle.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension, June 17 $11^h\ 31^m\ 14^s.0$.

	h	m	s		s	s
Sun's and Moon's R. A.	5	42	54.68	Hourly motions	10.40 and	147.49
Sun's declination	+23°	23′	36″.6	Hourly motion	+ 0′	04″.2
Moon's declination	+24	15	36 .9	Hourly motion	+ 4	04 .0
Sun's equa. hor. parallax			8 .7	Sun's true semidiam.	15	44 .3
Moon's equa. hor. parallax	57	44	.2	Moon's true semidiam.	15	43 .2

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time.		Longitude from Greenwich.		Latitude.	
	h	m	°	′	°	′
Eclipse begins June 17	9	00.4	123	03.3 E	25	40.8 N
Central Eclipse begins	10	30.3	81	31.6 E	50	01.7 N
Central Eclipse changes from annular to total	10	30.5	84	17.1 E	51	29.6 N
Central Eclipse at noon	11	31.2	172	39.1 W	38	22.1 N
Central Eclipse changes from total to annular	12	5.9	47	25.5 W	64	15.0 N
Central Eclipse ends	12	6.8	41	58.7 W	60	23.2 N
Eclipse ends	13	36.8	93	48.2 W	38	38.6 N

(3) *A Total Eclipse of the Moon*, 1909, November 26 will be visible generally throughout North America. The beginning will be visible in South America and northeastern Asia; the ending in northwestern South America, eastern and northern Asia and Australia.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of opposition in right ascension, November 26 $20^h\ 46^m\ 17^s.7$.

	h	m	s		s
Sun's right ascension	16	10	03.32	Hourly motion	10.67
Moon's right ascension	4	10	03.32	Hourly motion	151.26
Sun's declination	−21°	02′	56″.9	Hourly motion	− 0′ 27″.9
Moon's delination	+20	45	56 .0	Hourly motion	+10 03 .0
Sun's equa. hor. parallax			8 .9	Sun's true semidiam.	16 12 .8
Moon's equa. hor. parallax		60	11 .5	Moon's true semidiam.	16 23 .3

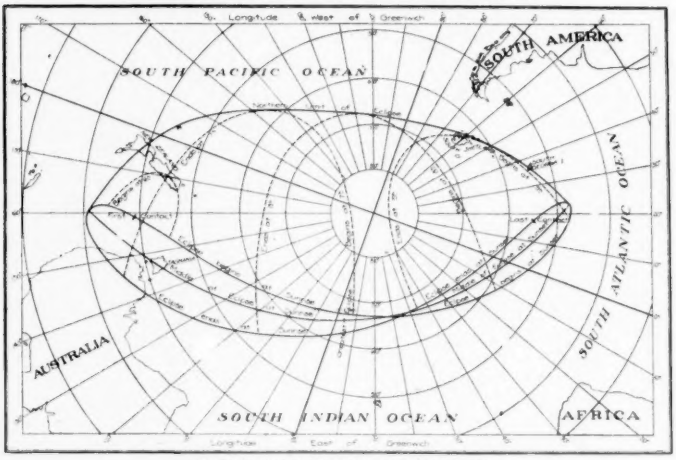
CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time			Central Standard Time	
		h	m	h	m
Moon enters penumbra	November 26	18	11.6	12	11.6
Moon enters shadow		19	11.0	13	11.0
Total Eclipse begins		20	13.6	14	13.6
Middle of Eclipse		20	54.6	14	54.6
Total Eclipse ends		21	35.6	15	35.6
Moon leaves shadow		22	38.2	16	38.2
Moon leaves penumbra		23	37.6	17	37.6

Magnitude of the eclipse = 1.372 (Moon's diameter = 1.0).

(4) *A Partial Eclipse of the Sun*, 1909, December 12, will be visible only in the south polar regions and parts of Australia, New Zealand and the south Shetland Islands.

PARTIAL ECLIPSE OF THE SUN DEC. 12TH 1909.



ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension, December 12 $8^h\ 9^m\ 29^s.3$.

Sun's and Moon's R. A.	$17^h\ 17^m\ 19^s.09$	Hourly motions	$11^s.03$ and $137^s.07$
Sun's declination	$-23°\ 05'\ 21.''6$	Hourly motion	$-\ 0'\ 11.''2$
Moon's declination	$-24\ 15\ 44.\ 2$	Hourly motion	$-\ 5\ 09\ .3$
Sun's equa. hor. parallax	$8.\ 9$	Sun's true semidiam.	$16\ 14\ .8$
Moon's equa. hor. parallax	$55\ 47.\ 9$	Moon's true semidiam.	$15\ 11\ .5$

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time.		Longitude from Greenwich.		Latitude.	
		h m	°	′	°	′
Eclipse begins	December 12	5 56.6	159	5.9 E	39	01.1 S
Greatest Eclipse		7 44.9	85	48.8 E	65	03 4 S
Eclipse ends		9 32.9	17	27.9 W	54	52.9 S

Magnitude of greatest eclipse = 0.541 (Sun's diameter = 1.0).

THE PLANETS.

The apparent courses of the planets among the stars for the year 1909 are shown upon the charts, Figures 1 and 2.

Mercury starts from a point in Sagittarius, moves eastward for a month, then describes a wide closed loop as it passes between the Earth and Sun in February, after that moves northeastward until June, when it again passes between the Earth and Sun, this time making a narrow closed loop; the movement then is eastward and southward until October when the path turns sharply on itself, then moves northward and returns to its eastward movement in a wide open bend. The path ends in Sagittarius about twelve degrees farther on than it started.

Venus has no retrograde movement this year. The dotted line representing her path begins in Scorpio, encircles the heavens and ends about 75° farther east than its starting point.

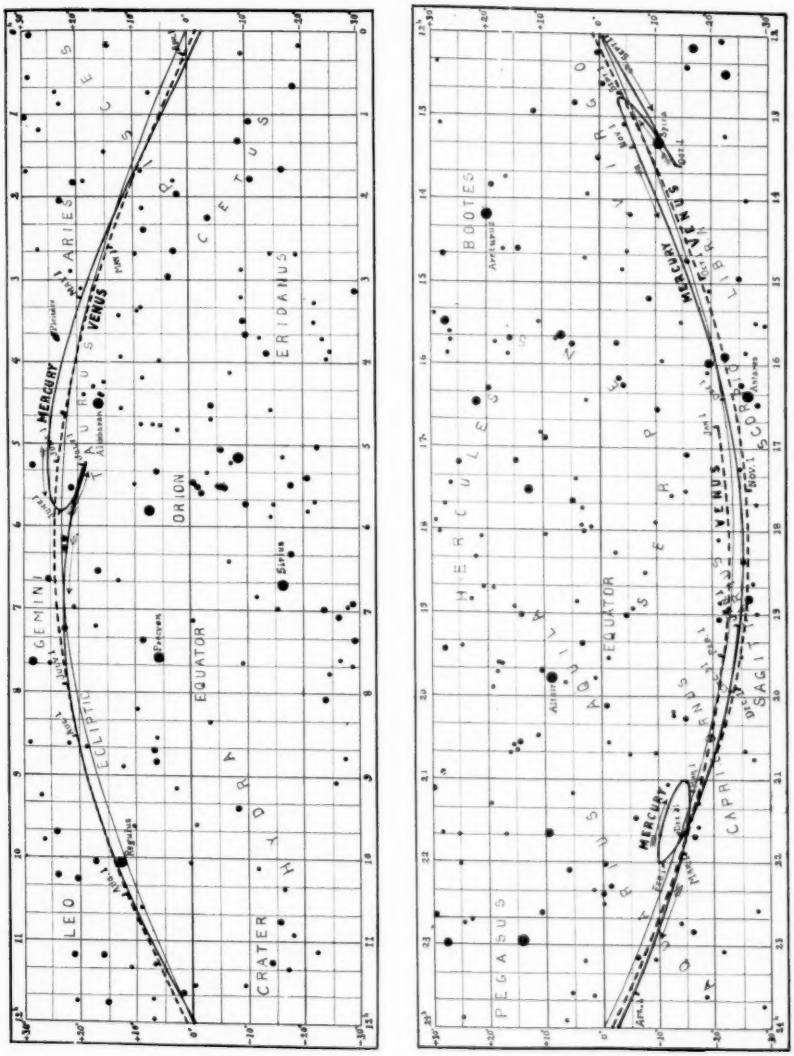


FIGURE 1. APPARENT PATHS OF MERCURY AND VENUS AMONG THE STARS DURING 1909

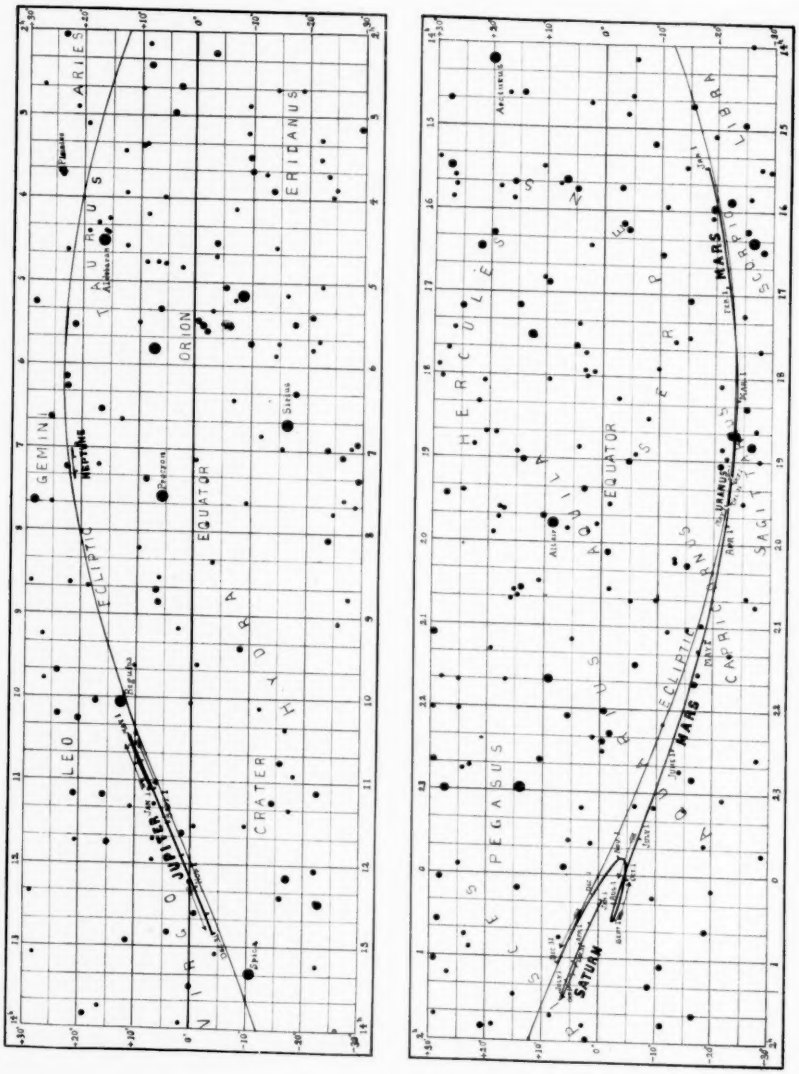


FIGURE 2. APPARENT PATHS OF MARS, JUPITER, SATURN, URANUS AND NEPTUNE AMONG THE STARS DURING 1909

Mars' path starts in Libra and ends in Pisces near Saturn. A great loop is produced by the retrograde movement in the autumn when Mars passes opposition. Sept. 18, five days before opposition, Mars will be at its nearest to the Earth, the distance then being a little over 36,000,000 miles. The apparent semidiameter of the planet will then be about 26″ so that the details of its surface marking should be comparatively easy to see. This should be a

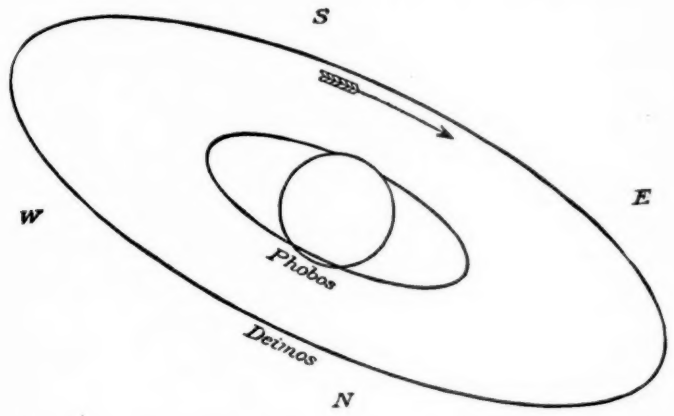


FIGURE 3. APPARENT ORBITS OF THE SATELLITES OF MARS, AT DATE OF OPPOSITION

favorable opposition for the study of the planet in both the northern and southern hemispheres of the Earth for the planet is near the equator at the time of opposition and so will be seen at a fair altitude by both northern and southern observers. The accompanying cut, Figure 3 shows the orbits of the satellites of Mars for this opposition.

Jupiter's course is along the descending slope of the ecliptic in Leo and Virgo, the motion being retrograde from Jan.1 to May 1 and direct for the remainder of the year. Jupiter will be at opposition Feb. 28 and so is in best position for study this winter.

Saturn's path is in Pisces and the movement is eastward until Aug. 5, then westward until Dec. 20. The rings of Saturn will open out quite a little this year the angle of depression of the Earth below the plane of the rings increas-

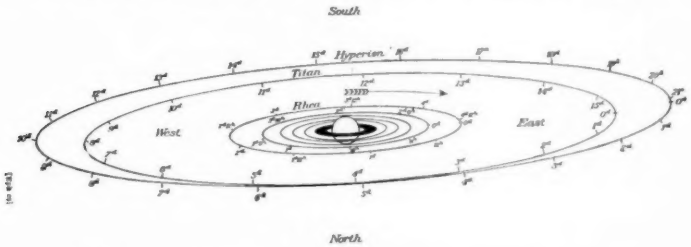
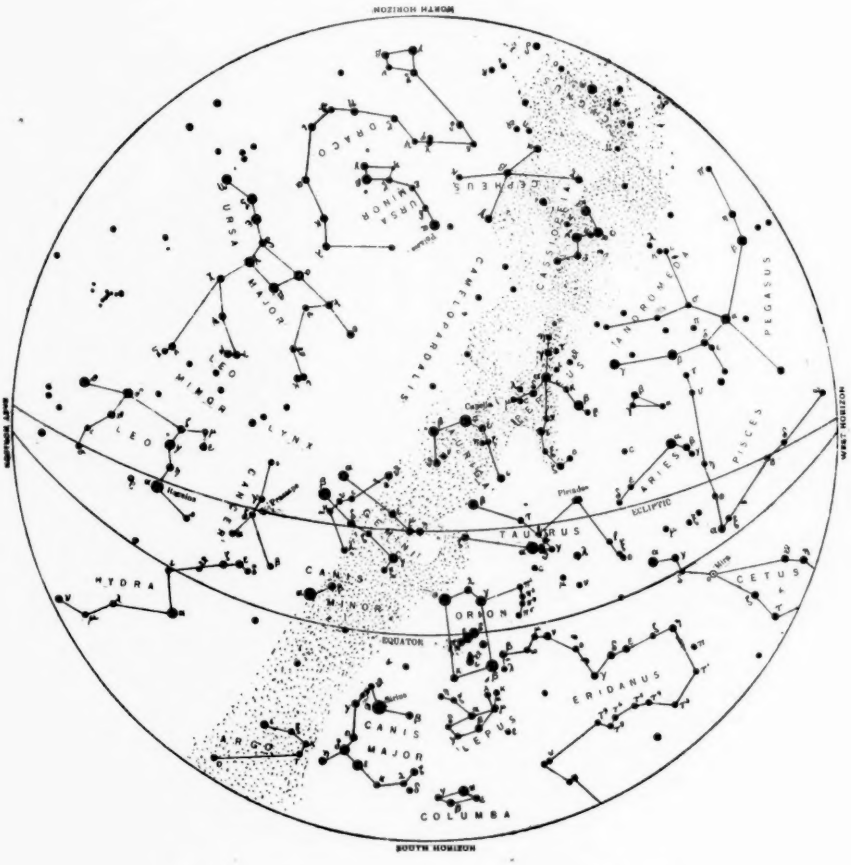


FIGURE 4. APPARENT ORBITS OE THE SATELLITES OF SATURN

ing from 5° to 13°. The planet will be at opposition Oct. 13. The orbits of the seven inner satellites of Saturn are shown in the cut Figure 4.

Uranus' apparent course is in Sagittarius. It is so short and so close to the ecliptic and to the path of Mars that it would not catch the eye upon the chart were it not for the name being printed above it. The motion is eastward until April 25, westward until Sept. 26 and after that eastward.

Neptune's path is a short one in Gemini just south of the star δ. The movement is westward until March 25, then eastward until Oct. 22 and westward for the remainder of the year.



THE CONSTELLATIONS AT 9:00 P. M., FEBRUARY 1, 1909.

PHASES OF THE MOON.

1909 Washington Mean Time.

New Moon.			First Quarter.			Full Moon.			Last Quarter.		
	h	m		h	m		h	m		h	m
						Jan. 5	21	4.4	Jan. 14	1	03.0
Jan. 21	7	03.5	Jan. 27	21	59.1	Feb. 4	15	16.6	Feb. 12	19	38.6
Feb. 19	17	43.8	Feb. 26	9	40 8	Mar. 6	9	47.5	Mar. 14	10	33.4
Mar. 21	3	03.0	Mar. 27	23	40.4	Apr. 5	3	20.1	Apr. 12	21	21.9
Apr. 19	11	43.0	Apr. 26	15	27.6	May 4	18	59.5	May 12	4	37.0
May 18	20	33.7	May 26	8	19.5	June 3	8	16.4	June 10	9	34.3
June 17	6	20.0	June 25	1	34.5	July 2	19	09.0	July 9	13	49.8
July 16	17	36.3	July 24	18	37 0	Aug. 1	4	05 7	Aug. 7	19	01.6
Aug. 15	6	46.4	Aug. 23	10	47.0	Aug. 30	11	59.5	Sept. 6	2	36.1
Sept. 13	22	00.4	Sept. 22	1	23.2	Sept. 28	19	57.1	Oct. 5	13	35.9
Oct. 13	15	05.1	Oct. 21	13	55.3	Oct. 28	4	58.7	Nov. 4	4	29.5
Nov. 12	9	10.0	Nov. 20	0	20.8	Nov. 26	15	43.6	Dec. 3	23	04.2
Dec. 12	2	50.4	Dec. 19	9	09.4	Dec. 26	4	21.6			

OCCULTATIONS VISIBLE AT WASHINGTON.

The list of occultations predicted in the *American Ephemeris* for the year 1909 numbers 121. As in former years we plan to give the list for each month in POPULAR ASTRONOMY one month ahead of time so that our readers may have ample notice of each.

The list for February is as follows:

Date 1909	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration. h m
Feb. 2	187 B Geminorum	6.3	16 32	137	17 19	248	0 47
7	ν Virginis	4.2	18 00	58	18 32	3	0 32
10	58 Virginis	6.5	10 47	116	11 51	301	1 04
10	598 B. Virginis	6.1	15 58	148	17 19	284	1 21
12	32 Libræ	5.9	14 50	118	16 08	303	1 18
13	58 G. Scorpii	6.2	14 25	98	15 31	313	1 06
15	70 B. Sagittarii	6.4	18 34	66	19 41	312	1 07
23	ν Piscium	4.6	6 58	92	7 53	215	0 55
25	33 B. Tauri	6.3	12 03	122	12 40	215	0 37
27	108 Tauri	6.2	3 46	71	5 05	249	1 19
28	8 Geminorum	6.1	6 57	94	8 27	254	1 30

COMETS.

The Morehouse Comet *c* 1908 will continue to be visible, to observers in the southern hemisphere, during at least the first half of 1909. Denning's comet 1894 I, which was due at perihelion about the middle of December 1908, has, up to the present writing, not been found and it may possibly be detected some time during the winter.

Of periodic comets known to be due in 1909 there are two, and one which is due at perihelion early in 1910 may be caught sight of in the latter part of this year. Halley's comet also, although its perihelion may not be reached until May 1910, will undoubtedly be seen in the autumn of 1909.

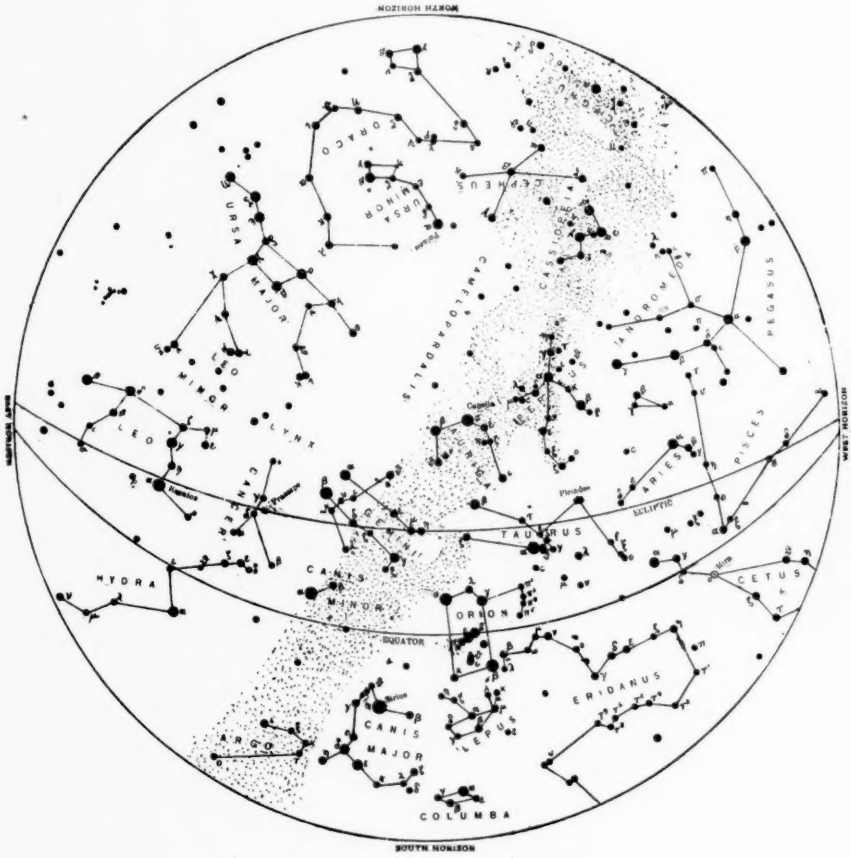
1. *Winnecke's* periodic comet should be at perihelion in November, but will then be near the farther side of the Earth's orbit where the Earth is in July so that the conditions will not be favorable to observations of the comet. It may possibly be detected during the summer.

2. *Perrine's* comet 1896 VII was not seen at its return in 1903 the conditions being unfavorable. This year unless the period has been appreciably changed by perturbations, it should return under conditions very similar to those

ing from 5° to 13°. The planet will be at opposition Oct. 13. The orbits of the seven inner satellites of Saturn are shown in the cut Figure 4.

Uranus' apparent course is in Sagittarius. It is so short and so close to the ecliptic and to the path of Mars that it would not catch the eye upon the chart were it not for the name being printed above it. The motion is eastward until April 25, westward until Sept. 26 and after that eastward.

Neptune's path is a short one in Gemini just south of the star δ. The movement is westward until March 25, then eastward until Oct. 22 and westward for the remainder of the year.



THE CONSTELLATIONS AT 9:00 P. M., FEBRUARY 1, 1909.

PHASES OF THE MOON.

1909 Washington Mean Time.

New Moon.			First Quarter.			Full Moon.			Last Quarter.		
	h	m		h	m		h	m		h	m
						Jan. 5	21	4.4	Jan. 14	1	03.0
Jan. 21	7	03.5	Jan. 27	21	59.1	Feb. 4	15	16.6	Feb. 12	19	38.6
Feb. 19	17	43.8	Feb. 26	9	40.8	Mar. 6	9	47.5	Mar. 14	10	33.4
Mar. 21	3	03.0	Mar. 27	23	40.4	Apr. 5	3	20.1	Apr. 12	21	21.9
Apr. 19	11	43.0	Apr. 26	15	27.6	May 4	18	59.5	May 12	4	37.0
May 18	20	33.7	May 26	8	19.5	June 3	8	16.4	June 10	9	34.3
June 17	6	20.0	June 25	1	34.5	July 2	19	09.0	July 9	13	49.8
July 16	17	36.3	July 24	18	37.0	Aug. 1	4	05.7	Aug. 7	19	01.6
Aug. 15	6	46.4	Aug. 23	10	47.0	Aug. 30	11	59.5	Sept. 6	2	36.1
Sept. 13	22	00.4	Sept. 22	1	23.2	Sept. 28	19	57.1	Oct. 5	13	35.9
Oct. 13	15	05.1	Oct. 21	13	55.3	Oct. 28	4	58.7	Nov. 4	4	29.5
Nov. 12	9	10.0	Nov. 20	0	20.8	Nov. 26	15	43.6	Dec. 3	23	04.2
Dec. 12	2	50.4	Dec. 19	9	09.4	Dec. 26	4	21.6			

OCCULTATIONS VISIBLE AT WASHINGTON.

The list of occultations predicted in the *American Ephemeris* for the year 1909 numbers 121. As in former years we plan to give the list for each month in POPULAR ASTRONOMY one month ahead of time so that our readers may have ample notice of each.

The list for February is as follows:

Date 1909	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration. h m
Feb. 2	187 B Geminorum	6.3	16 32	137	17 19	248	0 47
7	ν Virginis	4.2	18 00	58	18 32	3	0 32
10	58 Virginis	6.5	10 47	116	11 51	301	1 04
10	598 B. Virginis	6.1	15 58	148	17 19	284	1 21
12	32 Libræ	5.9	14 50	118	16 08	303	1 18
13	58 G. Scorpii	6.2	14 25	98	15 31	313	1 06
15	70 B. Sagittarii	6.4	18 34	66	19 41	312	1 07
23	ν Piscium	4.6	6 58	92	7 53	215	0 55
25	33 B. Tauri	6.3	12 03	122	12 40	215	0 37
27	108 Tauri	6.2	3 46	71	5 05	249	1 19
28	8 Geminorum	6.1	6 57	94	8 27	254	1 30

COMETS.

The Morehouse Comet *c* 1908 will continue to be visible, to observers in the southern hemisphere, during at least the first half of 1909. Denning's comet 1894 I, which was due at perihelion about the middle of December 1908, has, up to the present writing, not been found and it may possibly be detected some time during the winter.

Of periodic comets known to be due in 1909 there are two, and one which is due at perihelion early in 1910 may be caught sight of in the latter part of this year. Halley's comet also, although its perihelion may not be reached until May 1910, will undoubtedly be seen in the autumn of 1909.

1. *Winnecke's* periodic comet should be at perihelion in November, but will then be near the farther side of the Earth's orbit where the Earth is in July so that the conditions will not be favorable to observations of the comet. It may possibly be detected during the summer.

2. *Perrine's* comet 1896 VII was not seen at its return in 1903 the conditions being unfavorable. This year unless the period has been appreciably changed by perturbations, it should return under conditions very similar to those

at the time of its discovery in 1896. It is due at perihelion about December 12; and should be detected in the early autumn.

3. *Spitaler's* comet 1890 VII has not been seen since its disappearance in 1890, the returns in 1897 and 1903 being under unfavorable conditions. It is due at perihelion about February 1, 1910 under conditions almost as favorable as in 1890, and may be found in November or December 1909.

Three other comets which are due at perihelion early in 1910, Swift 1895 II, Giacobini 1896 V, and $Tempel_2$, will all be so unfavorably situated with reference to the Earth that they are not likely to be detected.

VARIABLE STARS.

The list of Algol Type stars whose periods are fairly well determined now numbers 67, and several more are suspected or have poorly determined periods. As in former years we are computing ephemerides of the minima of all of these stars except where the period is less than half a day. We endeavor to use the most accurate elements which we can find for each star and shall be glad if any of our readers will inform us of errors or better elements. For the stars of short period not of the Algol type the times of maxima are computed, except where the period is less than one day. These stars now number over 60 and the number is increasing at such a rate that it is doubtful if we can continue to calculate ephemerides of them all after this year. The calculations have been carried out to the nearest minute, although the predictions as printed will give only the nearest hour of Greenwich mean time.

METEOR SHOWERS.

The following list of the more brilliant meteor showers in Mr. Denning's catalogue is taken from the *The Companion to the Observatory* for 1908.

Date.	Radiant. α	Radiant. δ	Remarks.
Jan. 2-3	230°	+ 50°	Swift; long paths.
Apr. 20-22	271	+ 33	Swift.
May 1-6	338	— 2	Swift; streaks.
July 28	339	— 11	Slow; long.
Aug. 10-12	45	+ 57	Swift; streaks.
Oct. 18-20	92	+ 15	Swift; streaks
Nov. 14-16	150	+ 22	Swift; streaks.
Nov. 17-23	25	+ 43	Very slow; trains.
Dec. 10-12	108	+ 33	Swift; short.

The Perseids, with maximum on Aug. 11, are visible for a considerable period and their radiant point exhibits a motion to E. N. E. among the stars of about 1° per day. Its position for July 19 is about $\alpha = 19°$, $\delta = +50°$ and for Aug. 16 about $\alpha = 53°$, $\delta = +58°$.

COMET AND ASTEROID NOTES.

Ephemeris of Morehouse's Comet (1908 *c*)—The elements of the orbit of this comet by Dr. H. Kobold in *A.N.* 4275 were first referred to the ecliptic and mean equinox of 1909.0, then the constants for the equator were computed anew from them with the following results.

Elements		Constants for the Equator of 1909.0
T = 1908 Dec. 25.7744 G. M. T.		
ω = 171° 39′ 45″.4		$x = r[9.893173] \sin (154° 39′ 56″.9 + v)$
Ω = 103 12 47 .5	1909.0	$y = r[9.953286] \sin (267 39 17 .9 + v)$
i = 140 11 07 .2		$z = r[9.882511] \sin (202 10 45 .5 + v)$
$\log q$ = 9.975278		

With these elements and constants I have computed the following ephemeris giving *true* places for the mean equinox of 1909.0.

Ephemeris of Comet 1908 *c* for Greenwich Mean Midnight

1909		α 1909.0 h	m	s	δ 1909.0 °	′	log r	log Δ	Ab. time m	s	Br.
Jan.	1	18	49	46	−23	31.9	9.9757	0.2853	16	01	4.22
	17	18	49	19	−31	07.6	0.0110	0.2811	15	52	3.66
Feb.	2	18	48	10	−39	28.2	0.0643	0.2503	14	47	3.30
	18	18	42	38	−49	52.1	0.1237	0.2000	13	10	3.16
March	6	18	17	11	−63	47.9	0.1814	0.1419	11	31	3.17
	22	15	26	24	−78	54.6	0.2344	0.1029	10	32	2.97
April	7	10	02	19	−69	07.1	0.2823	0.1169	10	52	2.23
	23	9	15	10	−51	28.3	0.3253	0.1864	12	46	1.33
May	9	9	09	53	−38	50.6	0.3642	0.2754	15	40	0.74
	25	9	14	48	−30	47.9	0.3994	0.3613	19	05	0.42
June	10	9	23	33	−25	49.9	0.4316	0.4360	22	40	0.26
	26	9	33	57	−22	51.2	0.4610	0.4986	26	11	0.17
July	12	9	44	59	−21	12.1	0.4881	0.5500	29	28	0.12
	28	9	56	04	−20	28.3	0.5132	0.5914	32	25	0.087
Aug.	13	10	06	47	−20	24.4	0.5366	0.6239	34	57	0.067

The aberration time is assumed to be equal to 498.4 Δ seconds.

The brightness is computed from the formula, Br. $= r_0^2\Delta_0^2 : r^2\Delta^2$. The unit taken is the light on the date of discovery, 1908 September 1.5, for which date I find $\log r = 0.3164$, $\log \Delta = 0.2571$.

This comet will be in conjunction with the Sun in right ascension on 1909 January 1, at 23^h G.M.T., when, according to this ephemeris, it will be only about 48′ south of the Sun's center. If the comet had been one day later in arriving at perihelion it would have passed directly behind the Sun. It will again be in conjunction with the Sun on 1909 August 25, when it will be about 31° south of the Sun.

This work was begun before the ephemeris in the November *Observatory*, computed by Dr. Smart from the same elements and reprinted in the December Popular Astronomy, reached me. As my dates are all different from his and extend three months longer, besides the additional information given with them, it is hoped that this ephemeris will still be useful to indicate the course of the comet during the remainder of its period of visibility.

Princeton University Observatory, Zaccheus Daniel.
December 9, 1908.

Comet *c* 1908 (Morehouse).—The last photograph of this remarkable comet taken at Goodsell Observatory was on the evening of Nov. 27. An exposure of one hour, 6:12 to 7:15, C.S.T., shows the tail extending nearly 10° from the head and full of marvelous details. What a pity that for the month of December we could not have been on the other side of our orbit and so have come close to this wonderful object.

From now on it will be invisible to us in the northern hemisphere but observers in South America, Africa and Australia will have a splendid opportunity to continue a series of photographs which will be unique in the history of comets. After May 1909 it will again be visible to northern observers.

Halley's Comet.—Geocentric positions calculated by F. E. Seagrave.

1908	R.A. h m s	Decl. ° ′ ″	Log Δ
Dec. 13	6 5 58	+11 11 3	0.698872
17	6 2 11	+11 11 29	0.695116
21	5 58 19	+11 12 28	0.691853
25	5 54 24	+11 13 59	0.689101
29	5 50 26	+11 16 4	0.686871
1909			
Jan. 2	5 46 29	+11 18 43	0.685171

Numbering of Recently discovered Asteroids.—In *A. N.* 4278 Mr. J. Bauschinger gives the following permanent numbers to the small planets discovered in the latter half of 1907 and the first part of 1908, for which sufficient data have been obtained to determine their orbits.

1907 ZT = (639)
ZW = (640)
ZX = (641)
ZY = (642)
ZZ = (643)
AA = (644)
AB = (645)
AC = (646)
AD = (647)
AE = (648)
AF = (649)

1907 AM = (650)
AN = (651)
AU = (652) Jubilatrix
BK = (653) (= 1893 D)
1908 BM = (654) Zelinda
BS = (655)
BU = (656)
BV = (657)
BW = (658)
CS = (659)

Three have been found identical with planets whose orbits had been computed before:

1907 AH = (357) Ninina
1907 AQ = (528) Rezia
1908 BX = (615) [1906 VR]

For thirteen asteroids found by Joel H. Metcalf there are sufficient observations but the orbits have not yet been computed.

Elements of New Asteroids.

No.	Epoch	M ° ′ ″	ω ° ′ ″	Ω ° ′ ″
(639)	07 July 31.5	388 0 32.2	56 25 58.3	281 26 07.9
(640)	07 Oct. 22.5	81 31 30.9	24 47 52.8	235 58 21.3
(641)	07 Oct. 13.5	316 04 12.8	16 14 28.8	40 38 27.0
(642)	07 Oct. 13.5	249 13 36.1	114 18 07.8	7 21 52.5
(643)	07 Sept. 12.5	279 19 21.7	194 48 52.3	255 22 17.4
(645)	07 Nov. 4.5	327 29 32.7	156 33 46.8	280 35 36.5
(646)	07 Sept. 18.5	13 16 03.9	35 25 09.3	302 54 06.3
(647)	07 Sept. 16.5	311 18 23.4	173 15 10.9	254 44 06.5
(648)	07 Sept. 16.5	285 03 26.1	170 06 17.3	292 41 59.2
(649)	07 Sept. 11.5	7 04 30.0	346 49 08.9	357 12 59.5
(650)	07 Oct. 4.5	3 03 39.3	176 04 27.1	215 40 20.4
(651)	07 Oct. 4.5	9 56 25.8	349 23 52.7	38 49 59.8
(655)	08 Jan. 12.5	60 10 21.2	197 04 28.9	288 35 13.7
(656)	08 Jan. 25.5	334 23 21.2	321 33 02.4	186 15 21.0
(657)	08 Jan. 28.5	311 49 19.6	239 11 47.2	298 13 21.1
(658)	08 Feb. 9.5	57 58 54.4	65 06 46.0	352 11 10.1

ELEMENTS OF NEW ASTEROIDS CONTINUED.

	i			ϕ			μ	log a
	°	′	″	°	′	″	″	
(639)	8	36	14.0	5	43	14.7	681.063	0.377880
(640)	13	20	41.9	4	27	25.9	631.607	0.499707
(641)	1	43	47.5	7	15	52.8	1072.478	0.446412
(642)	8	12	23.4	8	02	31.3	627.201	0.501734
(643)	13	47	35.6	4	26	16.1	577.581	0.525596
(645)	9	29	24.0	12	49	55.4	782.814	0.437565
(646)	6	56	23.4	12	16	10.0	1000.933	0.366401
(647)	7	18	38.0	11	11	53.9	929.838	0.387734
(648)	9	59	11.4	12	44	41.0	624.825	0.502832
(649)	12	46	42.7	16	16	15.1	869.564	0.407136
(650)	2	33	31.8	10	46	12.3	918.478	0.391292
(651)	10	45	10.0	5	23	25.2	674.638	0.480624
(655)	3	09	43.2	13	32	58.1	649.597	0.491576
(656)	0	26	32.3	7	36	45.5	638.477	0.496574
(657)	10	16	48.2	6	15	55.4	843.374	0.415991
(658)	1	32	13.5	3	18	45.4	732.015	0.456992

All of these were computed by Mr. P. V. Neugebauer, except No. (640) by Prof. Kobold, (643) by Mr. G. Struve and (645) by Prof. Franz.

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

SY Androm.

	d	h
Feb.	16	14

U Cephei

Feb.	2	11
	4	23
	7	11
	9	23
	12	10
	14	22
	17	10
	19	22
	22	10
	23	12
	24	22
	27	9

Z Persei

Feb.	3	19
	6	20
	9	21
	12	23
	16	0
	19	1
	22	3
	25	4
	28	5

RY Persei

Feb.	2	7
	9	4
	16	0
	22	21

RZ Cassiop.

	d	h
Feb.	1	3
	2	8
	3	12
	4	17
	5	22
	7	2
	8	7
	9	12
	10	16
	11	21
	13	2
	14	6
	15	11
	16	16
	17	20
	19	1
	20	6
	21	11
	22	15
	23	20
	25	1
	26	5
	27	10
	28	15

RX Cephei

Feb.	13	9

Algol

Feb.	1	0
	3	20

Algol

	d	h
Feb.	6	17
	9	14
	12	11
	15	8
	18	5
	21	1
	23	22
	26	19

RT Persei

Feb.	1	21
	2	17
	3	14
	4	10
	5	6
	6	3
	6	23
	7	20
	8	16
	9	12
	10	9
	11	5
	12	2
	12	22
	13	18
	14	15
	15	11
	16	7
	17	4
	18	0

RT Persei

	d	h
Feb.	18	21
	19	17
	20	13
	21	10
	22	6
	23	3
	23	23
	24	19
	25	16
	26	12
	27	8
	28	5

λ Tauri

Feb.	2	11
	6	10
	10	9
	14	7
	18	6
	22	5
	26	4

RW Tauri

Feb.	1	5
	3	23
	6	18
	9	12
	12	7
	15	1
	17	19
	20	14

RW Tauri

	d	h
Feb.	23	8
	26	3
	28	21

RV Persei

Feb.	1	10
	3	10
	5	9
	7	8
	9	8
	11	7
	13	6
	15	6
	17	5
	19	4
	21	4
	23	3
	25	3
	27	2

RW Persei

Feb.	3	20
	17	1

RS Cephei

Feb.	7	5
	19	15

RY Aurigæ

Feb.	2	2
	4	20
	7	13
	10	7

Minima of Variable Stars of the Algol Type.—Continued.

RY Aurigae

	d	h
Feb.	13	0
	15	17
	18	11
	21	4
	23	22
	26	15

RZ Aurigæ

	d	h
Feb.	1	0
	4	1
	7	1
	10	1
	13	2
	16	2
	19	2
	22	3
	25	3
	28	4

RW Geminorum

	d	h
Feb.	1	22
	4	19
	7	16
	10	12
	13	9
	16	6
	19	3
	21	23
	24	20
	27	17

U Columbæ

	d	h
Feb.	1	0
	3	19
	6	15
	9	10
	12	5
	15	0
	17	19
	20	15
	23	10
	26	5

RW Monoc.

	d	h
Feb.	2	10
	4	8
	6	6
	8	4
	10	1
	11	23
	13	21
	15	19
	17	16
	19	14
	21	12
	23	10
	25	7
	27	5

RU Monoc.

	d	h
Feb.	1	13
	2	10
	3	8
	4	5
	5	3

RU Monoc.

	d	h
Feb.	6	0
	6	22
	7	19
	8	17
	9	14
	10	12
	11	9
	12	7
	13	4
	14	2
	14	23
	15	21
	16	18
	17	16
	18	13
	19	11
	20	8
	21	6
	22	3
	23	1
	23	22
	24	20
	25	17
	26	15
	27	12
	28	10

R Canis Maj.

	d	h
Feb.	1	23
	3	2
	4	5
	5	8
	6	12
	7	15
	8	18
	9	22
	11	1
	12	4
	13	7
	14	11
	15	14
	16	17
	17	20
	19	0
	20	3
	21	6
	22	9
	23	13
	24	16
	25	19
	26	22
	28	2

Y Camelop.

	d	h
Feb.	1	7
	4	14
	7	21
	11	5
	14	12
	17	19
	21	3
	24	10

Y Camelop.

	d	h
Feb.	27	17

RR Puppis

	d	h
Feb.	1	15
	8	2
	14	12
	20	22
	27	9

V Puppis

	d	h
Feb.	2	8
	3	19
	5	6
	6	17
	8	3
	9	14
	11	1
	12	12
	13	23
	15	10
	16	21
	18	8
	19	19
	21	6
	22	16
	24	3
	25	14
	27	1

X Carinæ

	d	h
Feb.	1	9
	2	11
	3	13
	4	15
	5	17
	6	19
	7	21
	8	23
	10	1
	11	3
	12	5
	13	7
	14	9
	15	11
	16	13
	17	15
	18	17
	19	19
	20	21
	21	23
	23	1
	24	3
	25	5
	26	7
	27	9
	28	11

S Cancri

	d	h
Feb.	9	22
	19	10
	28	21

S Velorum

	d	h
Feb.	5	23
	11	21

S Velorum

	d	h
Feb.	17	20
	23	18

RR Velorum

	d	h
Feb.	2	20
	4	17
	6	13
	8	10
	10	6
	12	3
	13	23
	15	20
	17	16
	19	13
	21	9
	23	6
	25	2
	26	23
	28	19

SS Carinæ

	d	h
Feb.	1	2
	4	10
	7	17
	11	0
	14	7
	17	14
	20	22
	24	5
	27	12

Z Draconis

	d	h
Feb.	1	18
	3	3
	4	11
	5	20
	7	5
	8	13
	9	22
	11	6
	12	15
	13	23
	15	8
	16	17
	18	1
	19	10
	20	18
	22	3
	23	11
	24	20
	26	5
	27	13
	28	22

SS Centauri

	d	h
Feb.	3	4
	5	15
	8	3
	10	14
	13	3
	15	13
	18	2
	20	13
	23	1

SS Centauri

	d	h
Feb.	25	12
	28	0

δ Libræ

	d	h
Feb.	1	13
	3	23
	6	6
	8	14
	10	22
	13	6
	15	14
	17	22
	20	6
	22	13
	24	21
	27	5

U Coronæ

	d	h
Feb.	1	11
	4	22
	8	9
	11	20
	15	7
	18	17
	22	4
	25	15

R Aræ

	d	h
Feb.	1	17
	6	3
	10	13
	15	0
	19	10
	23	20
	28	6

U Ophiuch

	d	h
Feb.	1	13
	2	9
	3	5
	4	1
	4	21
	5	18
	6	14
	7	10
	8	6
	9	2
	9	22
	10	18
	11	14
	12	11
	13	7
	14	3
	14	23
	15	19
	16	15
	17	11
	18	7
	19	4
	20	0
	20	20
	21	16
	22	12
	23	8

Minima of Variable Stars of the Algol Type.—Continued.

U Ophiuchi		RZ Draconis		RX Herculis		U Scuti		RV Lyræ	
d	h	d	h	d	h	d	h	d	h
Feb. 24	4	Feb. 1	20	Feb. 16	22	Feb. 4	18	Feb. 1	11
25	0	2	22	17	19	5	17	5	1
25	21	4	0	18	16	6	16	8	16
26	17	5	3	19	14	7	15	12	6
27	13	6	5	20	11	8	14	15	20
29	9	7	8	21	8	9	12	19	11
Z Herculis		8	10	22	6	10	11	23	1
Feb. 2	20	9	13	23	3	11	10	26	16
4	17	10	15	24	0	12	9		
6	20	11	17	24	22	13	8	U Sagittae	
8	17	12	20	25	19	14	7	Feb. 2	16
10	19	13	22	26	16	15	6	6	1
12	16	15	1	27	14	16	5	9	10
14	19	16	3	28	11	17	4	12	19
16	16	17	6	SX Sagittarii		18	3	16	5
18	19	18	8	Feb. 2	21	19	2	19	14
20	16	19	11	4	23	20	1	22	23
22	19	20	13	7	1	20	23	26	8
24	16	21	15	9	3	21	22		
26	19	22	18	11	5	22	4	SY Cygni	
28	16	23	20	13	7	23	20	Feb. 6	14
RS Sagittarii		24	23	15	9	24	19	12	15
Feb. 4	6	26	1	17	10	25	18	18	15
6	16	27	4	19	12	26	17	24	15
7	2	28	6	21	14	27	16		
11	12	RX Herculis		23	16	28	15	WW Cygni	
13	22	Feb. 1	19	25	18			Feb. 3	14
16	8	2	16	27	20	RX Draconis		6	21
18	18	3	13	RR Draconis		Feb. 1	13	9	29
21	4	4	11	Feb. 2	7	3	11	13	13
23	14	5	8	5	3	5	8	16	20
26	0	6	5	7	23	7	6	20	4
28	10	7	3	10	19	9	3	23	11
V Serpentis		8	0	13	15	11	0	26	19
Feb. 1	9	8	21	16	11	12	22		
4	20	9	19	19	7	14	19		
8	7	10	16	22	3	16	17	SW Cygni	
11	18	11	13	24	23	18	14	Feb. 2	5
15	5	12	11	27	19	20	12	6	19
18	15	13	8	U Scuti		22	9	11	8
22	2	14	5	Feb. 1	21	24	7	15	22
25	13	15	3	2	20	26	4	20	12
		16	0	3	19	28	2	25	2

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SY Cassiop.		RW Cassiop.		Y Aurigæ		Y Aurigæ		W Geminorum	
d	h	d	h	d	h	h	d	d	h
Feb. 5	0	(−5	19)	(−0	18)	Feb. 27	1	Feb. 10	10
9	2	Feb. 12	2	Feb. 3	22	T Monoc.		18	8
13	4	26	22	7	18	(−9	23)	26	5
17	5	RX Aurigæ		11	15	Feb. 20	14	ζ Geminorum	
21	7	(−4	0)	15	12	W Geminorum		(−5	0)
25	9	Feb. 12	10	19	8	(−2	2)	Feb. 9	8
		24	1	23	5	Feb. 2	12	19	12

Maxima of Variable Stars of Short Period not of the Algol Type

Continued.

RU Camelop.

	d	h
	(−9.	12)
Feb.	16	22

V Carinæ

	(−2	4)
Feb.	2	20
	9	13
	16	6
	22	23

T Velorum

	(−1	10)
Feb.	1	19
	6	11
	11	2
	15	17
	20	9
	25	0

W Carinæ

	(−1	0)
Feb.	1	4
	5	13
	9	21
	14	6
	18	15
	23	0
	27	9

S Muscæ

	(−3	11)
Feb.	3	13
	13	4
	22	20

T Crucis

	(−2	2)
Feb.	2	13
	9	7
	16	1
	22	18

R Crucis

	(−1	10)
Feb.	3	18
	9	13
	15	9
	21	5
	27	1

S Crucis

	d	h
	(−1	12)
Feb.	4	16
	9	9
	14	1
	18	18
	23	10
	28	3

RZ Centauri

Feb.	1	13
	2	12
	3	10
	4	9
	5	7
	6	6
	7	4
	8	3
	9	1
	10	0
	10	22
	11	21
	12	19
	13	18
	14	16
	15	15
	16	13
	17	12
	18	10
	19	9
	20	7
	21	6
	22	4
	23	3
	24	2
	25	0
	25	22
	26	21
	27	20
	28	18

W Virginis

	(−8	5)
Feb.	17	21

V Centauri

	d	
	(−1	11)
Feb.	5	21
	11	8
	16	20
	22	8
	27	20

R Triang. Austr.

	(−1	0)
Feb.	1	21
	5	7
	8	16
	12	1
	15	11
	18	20
	22	5
	25	15
	29	0

S Triang. Austr.

	(−2	2)
Feb.	5	1
	11	9
	17	16
	24	3

S Normæ

	(−4	10)
Feb.	7	7
	17	1
	26	19

RV Scorpii

	(−1	10)
Feb.	4	1
	10	3
	16	4
	22	6
	28	7

RV Ophiuchi Minimum.

	d	h
Feb.	3	10
	7	2
	10	19
	14	11
	18	4
	21	20
	25	13

X Sagittarii

	(−2	22)
Feb.	5	13
	12	13
	19	13
	26	13

Y Ophiuchi

	(−6	5)
Feb.	12	8

W Sagittarii

	(−3	0)
Feb.	4	10
	12	1
	19	15
	27	5

Y Sagittarii

	(−2	2)
Feb.	6	1
	12	6
	18	0
	23	19

U Sagittarii

	(−2	23)
Feb.	3	5
	9	23
	16	17
	23	11

β Lyræ

	(−3	2)
	(−3	7)
Feb.	0	21
	13	19
	20	11

κ Pavonis

	d	h
	(−4	7)
Feb.	9	20
	18	23
	28	1

U Aquilæ

	−2	4)
Feb.	1	1
	8	2
	15	3
	22	3

U Vulpeculæ

	(−2	3)
Feb.	3	22
	11	22
	19	21
	27	21

SU Cygni

	(−1	7)
Feb.	2	17
	6	13
	10	9
	14	6
	18	2
	21	22
	25	19

η Aquilae

	(−2	6)
Feb.	5	15
	12	20
	20	0
	27	4

S Sagittae

	(−3	10)
Feb.	1	2
	9	11
	17	20
	26	6

X Vulpeculæ

	(−2	1)
Feb.	4	11
	10	18
	17	2
	23	9

Approximate Magnitudes of Variable Stars on December 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	h	R. A. 1900. m	Decl. 1900. °	′	Magn.	Name.	h	R.A. 1900. m	Decl. 1900. °	′	Magn.
X Androm.	0	10.8	+46	27	12.8*d*	RW Androm.	0	41.9	+32	8	13.5*d*
T Androm.		17.2	+26	26	8.5 *i*	V Androm.		44.6	+35	6	10.5 *i*
T Cassiop.		17.8	+55	14	7.7 *i*	RR Androm.		45.9	+33	50	13.6*d*
R Androm.		18.8	+38	1	9.7*d*	RV Cassiop.		47.1	+46	53	14.0
S Ceti		19.0	− 9	53	9.3 *i*	W Cassiop.		49.0	+58	1	9.1
Y Cephei		31.3	+79	48	11.6*d*	U Androm.	1	9.8	+40	11	<14
U Cassiop.		40.8	+47	43	9.6 *i*	S Piscium		12.4	+ 8	24	<14

Approximate Magnitudes of Variable Stars on Dec. 1, 1908—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A 1900 h	m	Decl. 1900 °	′	Magn.
U Piscium	1	17.7	+12	21	10.9 *i*	V Gemin.	7	17.6	+13	17	9.7*d*
S Cassiop.		12.3	+72	5	12.2*d*	S Can. Min.		27.3	+ 8	32	10.6
R Piscium		25.5	+ 2	22	13.9*d*	T Can. Min.		28.4	+11	58	9.0
RU Androm.		32.8	+38	10	13.1*d*	Z Puppis		28.3	−20	27	<12
Y Androm.		33.7	+38	50	<14	S Gemin.		37.0	+23	41	<12.8
X Cassiop.		49.8	+58	46	10.5	T Gemin.		43.3	+23	59	9.8*d*
U Persei		53.0	+54	20	8.0	U Puppis		56.1	−12	34	12.2*d*
S Arietis		59.3	+12	3	<14	R Cancri	8	11.0	+12	2	10.0*d*
R Arietis	2	10.4	+24	35	13.1	V Cancri		16.0	+17	36	10.0*d*
W Androm.		11.2	+43	50	11.0*d*	RT Hydrae		24.7	− 5	59	8.0
Z Cephei		12.8	+81	13	<14	U Cancri		30.0	+19	14	<12.6
o Ceti		14.3	− 3	26	4.7*d*	X Urs. Maj.		33.7	+50	30	10.0 *i*
S Persei		15.7	+58	8	9.2	S Hydrae		48.4	+ 3	27	8.4 *i*
R Ceti		20.9	− 0	38	13.4*d*	T Hydrae		50.8	− 8	46	7.8 *i*
RR Persei		21.7	+50	49	<12.6	T Cancri		51.0	+20	14	8.6
U Ceti		28.9	−13	35	9.2*d*	S Pyxidis	9	0.7	−24	41	12.0*d*
R Trianguli		31.0	+33	50	8 1 *i*	W Cancri		4.0	+25	39	8.5 *i*
T Arietis		42.8	+17	6	9.0	Y Draconis		31.1	+78	18	12.6 *i*
W Persei		43.2	+56	34	8.8	R Leo. Min.		39.6	+34	58	7.4 *i*
U Arietis	3	5.5	+14	25	13.5	RR Hydrae		40.4	−23	34	12.0*d*
X Ceti		14.3	− 1	26	12.5*d*	R Leonis		42.2	+11	54	5.5 *i*
Y Persei		20.9	+43	50	8.3 *i*	Y Hydrae		46.4	−22	33	7.0
R Persei		23 7	+35	20	8.8 *i*	V Leonis		54.5	+21	44	13.0*d*
Nov. Per. 2		24.4	+43	34	12.6	R Urs. Maj.	10	37.6	+69	18	11.5*d*
T Tauri	4	16.2	+19	18	10.0	W Leonis		48.4	−14	15	<12.2
R Tauri		22.8	+ 9	56	13.5*d*	S Leonis	11	5.7	+ 6	0	12.4
W Tauri		22.2	+15	49	8.6 *i*	R Comae		59.1	+19	20	<12.4
S Tauri		23.7	+ 9	44	<14	T Virginis	12	9.5	− 5	29	9.8*d*
T Camelop.		30.4	+65	57	10.2 *i*	R Corvi		14.4	−18	42	11.4
RX Tauri		32.8	+ 8	9	<12	T Can. Ven.		25.2	+32	3	11.8
X Camelop.		32.6	+74	56	10.6*d*	SS Virginis		20.1	+ 1	19	7.3
V Tauri		46.2	+17	22	<13	Y Virginis		28.7	− 3	52	10.0 *i*
R Orionis		53.6	+ 7	59	<12	T Urs. Maj.		31.8	+60	2	10.6*d*
R Leporis		55.0	−14	57	8.0	R Virginis		33.4	+ 7	32	7.2*d*
V Orionis	5	0.8	+ 3	58	13.0*d*	RS Urs. Maj.		34.4	+59	2	9.8 *i*
T Leporis		0.6	−22	2	10.5*d*	S Urs. Maj.		39.6	+61	38	10.8*d*
R Aurigae		9.2	+53	28	8.6 *i*	RU Virginis		42.2	+ 4	42	10.6
S Aurigae		20.5	+34	4	8.6	U Virginis		46.0	+ 6	6	8.0
W Aurigae		20.1	+36	49	10.1*d*	RT Virginis		57.6	+ 5	43	8.5
S Orionis		24.1	− 4	46	8.6*d*	RV Virginis	13	2.8	−12	38	12.0
T Orionis		30.9	− 5	32	10.0	V Virginis		22.6	− 2	39	10.6
S Camelop.		30.2	+68	45	10.8*d*	R Hydrae		24.2	−22	46	7.6*d*
RR Tauri		33.3	+26	19	12.2*d*	S Virginis		27.8	− 6	41	6.5
U Aurigae		35.6	+31	59	10.5*d*	T Urs.Min.		32.6	+73	56	9.5*d*
U Orionis		49.9	+20	10	11.6*d*	R Can. Ven.		44.6	+40	2	8.3 *i*
Z Aurigæ		53.6	+53	18	9.5	RR Virginis		59.6	− 8	43	<12
X Aurigae	6	4.4	+50	15	11.2*d*	Z Virginis	14	5.0	−12	50	12.0
V Aurigae		16.5	+47	45	10.0 *i*	U Urs. Min.		15.1	+67	15	8.3 *i*
V Monoc.		17.7	− 2	9	11.0*d*	S Bootis		19.5	+54	16	9.5 *i*
R Monoc.		33.7	+ 8	49	10.5	V Bootis		25.7	+39	18	8.5
S Lyncis		35.9	+58	0	13.5*d*	R Camelop.		25.1	+84	17	8.4 *i*
X Gemin.		40.7	+30	23	12.1*d*	R Bootis		32.8	+27	10	<12
W Monoc.		47.5	− 7	2	10.0	R Coronae		44.4	+28	28	6.0
Y Monoc.		51.3	+11	22	10.0 *i*	RR Herculis	16	1.5	+50	46	8.7
X Monoc.		52.4	− 8	56	9.1*d*	W Coronae		11.8	+38	3	11.4*d*
R Lyncis		53.0	+55	28	8.3 *i*	U Herculis		21.4	+19	7	10.2*d*
RS Gemin.		55.2	+30	40	10.1 *i*	W Herculis		31.7	+37	32	11.6*d*
V Can. Min.	7	1.5	+ 9	2	10.6*d*	R Draconis		32.4	+66	58	8.4
R Gemin.		1.3	+22	52	9.6*d*	RV Herculis		56.8	+31	22	11.0*d*
R Can. Min.		3.2	+10	11	9.0 *i*	RT Herculis	17	6.8	+27	11	11.6 *i*
RR Monoc.		12.4	+ 1	17	10.0	RS Herculis		17.5	+23	1	12.8*d*

Approximate Magnitudes of Variable Stars on Dec. 1, 1908—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
T Draconis	17	54.8	+58	14	10.1	S Delphini	20	38.5	+16	44	11.4*d*
— Draconis		54.7	+58	14	11.8	V Cygni		38.1	+47	47	11.8*d*
RY Herculis		55.4	+19	29	12.2*d*	Y Aquarii		39.2	− 5	12	9.7 *i*
V Draconis		56.3	+54	53	10.4 *i*	U Capricorni		42.6	−15	9	14.0*d*
T Herculis	18	5.3	+31	0	9.4*d*	T Delphini		40.7	+16	2	14.0
W Draconis		5.4	+65	56	9.5 *i*	V Aquarii		41.8	+ 2	4	8.6
X Draconis		6.8	+66	8	9.5 *i*	W Aquarii		41.2	− 4	27	11.4*d*
RY Ophiuchi		11.6	+ 3	40	9.0 *i*	V Delphini		43.2	+18	58	13.7*d*
W Lyrae		11.5	+36	38	12.2*d*	T Aquarii		44.7	− 5	31	11.6 *i*
SV Herculis		22.3	+24	58	14.0*d*	RZ Cygni		48.5	+46	59	13.6*d*
T Serpentis		23.9	+ 6	14	9.4 *i*	X Delphini		50.3	+17	16	11.2*d*
RZ Herculis		32.7	+25	58	13.4*d*	— Delphini		50.3	+17	13	12.8
X Ophiuchi		33.6	+ 8	44	8.4 *i*	UX Cygni		50.9	+30	2	13.2
RY Lyrae		41.2	+34	34	9.5 *i*	R Vulpeculae		59.9	+23	26	10.7*d*
RW Lyrae		42.1	+43	32	12.8*d*	V Capric.	21	1.8	−24	19	12.8
Z Lyrae		56.0	+34	49	14.0*d*	TW Cygni		1.8	+29	0	12.2*d*
RX Lyrae		50.4	+32	42	12.2*d*	X Capricorni		2.8	−21	45	12.0*d*
RT Lyrae		57.8	+37	22	13.4*d*	X Cephei		3.6	+82	40	12.0*d*
R Aquilae	19	1.6	+ 8	5	7.0*d*	RS Aquarii		5.8	− 4	27	10.4 *i*
V Lyrae		5.2	+29	30	14.0	Z Capricorni		5 0	−16	35	12.5*d*
RX Sagittarii		8.7	−18	59	13.4	R Equulei		8.4	+12	23	12.2*d*
S Lyrae		9.1	+25	50	14.0	T Cephei		8.2	+68	5	9.6*d*
RS Lyrae		9.3	+33	15	11.0 *i*	RR Aquarii		9.8	− 3	19	12.5*d*
RU Lyrae		9.1	+41	8	13.4*d*	X Pegasi		16.3	+14	2	10 6 *i*
U Draconis		9.9	+67	7	13.4	T Capricorni		16.5	−15	35	9.4 *i*
W Aquilae		10.0	− 7	13	13.9*d*	Y Capricorni		28.9	−14	25	13.6*d*
TZ Cygni		13.4	+50	0	10.2	S Cephei		36.5	+78	10	10.4*d*
U Lyrae		16.6	+37	42	10.8	RU Cygni		37.3	+53	52	7.8 *i*
TY Cygni		29.8	+28	6	13.0*d*	RR Pegasi		40.0	+24	33	14.0
R Cygni		34.1	+49	58	11.4*d*	V Pegasi		56.0	+ 5	38	12.0*d*
RV Aquilae		35.9	+ 9	42	<14	U Aquarii		57.9	−17	6	12.6*d*
RT Aquilae		33.3	+11	30	12.9 *i*	RT Pegasi		59.8	+34	38	11.6*d*
RT Cygni		40.8	+48	32	8.4 *i*	T Pegasi	22	4.0	+12	3	11.4 *i*
TU Cygni		43.3	+48	49	14.0*d*	Y Pegasi		6.8	+13	52	13.9*d*
X Aquilae		46.5	+ 4	13	9.8*d*	RS Pegasi		7.4	+14	4	13.5*d*
χ Cygni		46.7	+32	40	12.4*d*	X Aquarii		13.2	−21	24	13.7*d*
RS Aquilae		53.7	− 8	9	10.9 *i*	RT Aquarii		17.7	−22	34	9.8*d*
Z Cygni		58.6	+49	46	11.1*d*	RV Pegasi		21.0	+29	58	10.3*d*
SY Aquilae	20	2.3	+12	39	13.3*d*	S Lacertae		24.6	+39	48	11.2 *i*
S Cygni		3.4	+57	42	11.4 *i*	R Lacertae		38.8	+41	51	14.0
R Capricorni		5.7	−14	34	10.5 *i*	S Aquarii		51.8	−20	53	11.4 *i*
S Aquilae		7.0	+15	19	10.8*d*	RW Pegasi		59.2	+14	46	13.8*d*
RU Aquilae		8.0	+12	42	12.0 *i*	R Pegasi	23	1.6	+10	0	10 8*d*
W Capricorni		8.6	−22	17	11.0 *i*	V Cassiop.		7.4	+59	8	8.8 *i*
Z Aquilae		9.8	− 6	27	9.2 *i*	W Pegasi		14.8	+25	44	7.6 *i*
RS Cygni		9.8	+38	28	8.8	S Pegasi		15.5	+ 8	22	12.2
R Delphini		10.1	+ 8	47	12.1 *i*	ST Androm.		33.8	+35	13	10.2*d*
RT Capricorni		11.3	−21	38	7.6	R Aquarii		38.6	−15	50	10.2*d*
SX Cygni		11.6	+30	46	12.8*d*	Z Cassiop.		39.7	+56	2	13.8*d*
WX Cygni		14.8	+37	8	10.8 *i*	Z Aquarii		47.1	−16	25	8.6
U Cygni		16.5	+47	35	10.2*d*	RR Cassiop.		50.7	+53	8	<13.5
RW Cygni		25.2	+39	39	7.8 *i*	V Ceti		52.8	− 9	31	10.5 *i*
RU Capricorni		26.7	−22	2	13.0	R Cassiop.		53.3	+50	50	8.0
Z Delphini		28.1	+17	7	9.2 *i*	Z Pegasi		55.0	+25	21	9.6 *i*
ST Cygni		29.9	+54	38	12.4*d*	W Ceti		57.0	−16	14	8.0*d*
Y Delphini		36.9	+11	31	13.0 *i*	Y Cassiop.		58.2	+55	7	<13.8

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Vassar, Whitin, Swartz and Harvard Observatories.

29 New Variables near Nova Sagittarii.—In the Harvard Circular No. 141 Professor Pickering gives a list of 29 new variables found by Miss Leavitt from an examination of photographs of the region around Nova Sagittarii extending in right ascension from $18^h\ 41^m$ to $19^h\ 7^m$ and in declination from $-10°$ to $-15°$. In the same region 22 more stars were suspected but the variation was not definitely established. As these stars are all faint, only two being brighter than magnitude 12:0 at maximum, we shall not give their positions here. The 51 stars have been assigned the numbers 60 to 110.1908.

28 New Variable Stars.—In the Harvard Circular No. 142 Professor Pickering gives a list of 28 new variables, discovered by Miss Leavitt in an examination of plates covering the regions of the Harvard maps Nos. 30 and 33. These have been assigned the numbers 111 to 137. 1908. Their positions are as follows:

Provisional Designation	Harvard Number	BD	R.A. 1900 h m s	Decl. 1900 ° ′	Mag.
111.1908 Serpentis	3131	− 1 3036	15 08 50	− 1 31.1	9.4 10.2
112.1908 Serpentis	3132	+ 2 2940	15 10 58	+ 2 32.5	10.1 10.9
113.1908 Serpentis	3133	+ 2 2972	15 26 00	+ 2 00 8	9.3 10.1
114.1908 Libræ	3134	−15 4194	15 43 26	−15 13.9	9.6 10.6
115.1908 Ophiuchi	3135	− 6 4393	16 11 06	− 6 43.8	9.2 10.0
116.1908 Ophiuchi	3136		16 12 34	− 6 24.8	10.5 11.2
117.1908 Serpentis	3137		16 14 05	− 2 15.4	8.9 14.5
118.1908 Ophiuchi	3138	−11 4154	16 14 20	−11 48.6	9.5 10.2
119.1908 Herculis	3139	+13 3174	16 31 32	+13 30.6	9.8 10.6
120.1908 Herculis	3140	+12 3081	16 40 55	+12 19.0	9.4<11.0
121.1908 Ophiuchi	3141	+ 3 3281	16 44 38	+ 3 48.6	9.8 11.1
S S Ophiuchi			16 52 39	− 2 36.4	9.6 11.0
122.1908 Ophiuchi	3143		16 59 05	+ 5 07.7	10.2 11.2
123.1908 Aquarii	3144		21 10 11	− 0 19.6	10.0 11.0
124.1908 Aquarii	3145	− 2 5494	21 11 11	− 2 38.7	11.0<12.0
125.1908 Aquarii	3146	−11 5574	21 14 51	−11 13.5	9.2 10.2
126.1908 Aquarii	3147		21 17 46	− 7 30.4	11.0<12.5
127.1908 Aquarii	3148	+ 0 4716	21 17 58	+ 0 24.4	11.0<12.5
128.1908 Aquarii	3149		22 31 06	+ 2 47.1	10.7 11.7
129.1908 Pegasi	3150	+12 4678	21 40 15	+12 13.3	9.8<12.0
130.1908 Aquarii	3151	− 5 5649	21 45 31	− 5 35.4	10.8 12.0
131.1908 Pegasi	3152	+ 2 4488	22 13 05	+ 2 14.2	9.8 10.6
132.1908 Pegasi	3153	+12 4801	22 13 24	+13 05.2	10 0 11.2
133.1908 Aquarii	3154	−15 6193	22 14 32	−14 54.3	11.0 12.5
134.1908 Aquarii	3155	− 7 5753	22 15 47	− 7 28.5	9.2 9.9
135.1908 Aquarii	3156	−16 6074	22 17 54	−15 50.3	10.6 11.3
136.1908 Aquarii	3157	−13 6289	22 46 46	−13 28.4	9.8 10 5
137.1908 Aquarii	3158	−10 6016	22 49 42	− 9 54 5	10-5 11.5

Notes—114.1908 probably of Algol type. 115.1908 Algol type; minimum $=2410001.78 + 2^d.44596$ E; recent observations better satisfied by the formula $2410002.320 + 2^d.44578$ E. 116.1808 Algol type; minimum $=2410001.704 + 2^d.06330$ E. 117.1908. This star was at its maximum brightness on a large number of plates taken between May 5 and Sept. 21, 1903; in 1904 and 1905 it was much fainter; in 1906 the plates do not show it except one taken May 28 when it was about magnitude 14.5. 120.1908. Period apparently long. 121.1908. Period probably short; an eleventh magnitude star precedes about 4^s. SS Ophiuchi. Period probably long. 123.1908. Period short; a twelfth magnitude star follows about 6^s. 124.1908. Period does not exceed two months. 125.1908. Perhaps of Algol type. 126.1908. A twelfth magnitude star precedes about 6^s. 129.1908. Period probably long. 130.1908. Period probably long. 134, 135 and 136.1908. Apparently of the Algol type.

SS Aurigæ.—This variable of the U Geminorum type passed through a maximum in the last days of August and the first days of September. It appears to have risen suddenly from below the 13.5 magnitude on Aug. 27 to 11.0 on Aug. 28, then increased more slowly, reaching its maximum magnitude of about 10.3 Sept.1 or 2, then dropped to 12.1 Sept. 7, 13.2 Sept. 9, and to have become invisible (<13.5) Sept. 10 or 11. The duration of the maximum was about 13 days.

ST Virginis and ST Ophiuchi.—In *A.N.* 4284 Mr. Paul Guthnick gives new elements and light curves of these two Antalgol type stars:

ST Virginis Max. = 2418093.487 Gr. m. t. $+$ $9^h\ 51^m\ 16^s.5$ ($0^d.410608$) E

ST Ophiuchi Max. = 2418088.5066 Gr. m. t. $+10^h\ 48^m\ 31^s.35$ (0.450363) E.

The maximum of ST Virginis is very sharp, rising from magnitude 11.4 to 10.3 in 79 minutes, remaining at 10.3 for only a few minutes, then falling rapidly at first then more slowly, occupying $4^h\ 55^m$ in the fall and remaining at minimum for $3^h\ 36^m$.

ST Ophiuchi rises from magnitude 12.3 to 11.0 in 46 minutes, remains near maximum for 53 minutes then falls to minimum in $5^h\ 46^m$ and remains at minimum for $4^h\ 9^m$.

Variable Star 142.1908 Cassiopeiæ.—This star has been found upon three photographs taken at Heidelberg. On Jan. 2, 1908 it was of magnitude 14, and on Sept. 26 1898 on two plates of short exposure it appears as of magnitude 11.0. It must apparently be classed with the long period variables.

New Variable 143.1908 Persei.—In *A.N.* 4283 attention is called to the star BD $+$ 33° 715, magnitude 9.5, which on Oct. 30, 1908 was found to be missing from the sky. The BD position of the star is based upon two observations nearly three years apart, which agree fairly well.

α 1855 $3^h\ 37^m\ 52^s.4$; $\delta = +33°\ 52'.0$.

Upon a photograph taken at Potsdam Nov. 30, 1894 the star is present with a magnitude 10.0. On Oct. 15, 1899 it was fainter than 10.5.

Y Leonis (165.1907).—In *A.N.* 4280 Mr. F. Ristenpart gives new elements of this variable as follows:

Minimum = 2418054^d.428 (Paris m t.) $+$ $1^d.686237$ E.

The variable is of the Algol type, and ranges from 9.3 to 11.2 magnitude. Its position for 1900.0 is

$\alpha = 9^h\ 31^m\ 05^s$ $\delta = +26°\ 40'.8$

Variable Star Notes.

O CETI

As this well-known variable needs no magnifying power in its brightest phases, they have been observed repeatedly, and inequalities in its period and

maxima are of occasional occurrence. The decline of a normal maximum in last September was recorded as follows:

1908 September 29, 11:20 P. M.	—Brighter than Alpha Piscium. In opera-glass, nearer to Alpha Ceti than to Gamma Ceti; with naked eye, nearer to the latter. Night clear.
October 1, 8, 16	—The same.
October 18, 20, 24	—With naked eye, and with opera-glass nearer to Gamma than to Alpha Ceti.
October 26	—At even altitudes, the variable seems two tenths brighter tha Gamma Ceti in the opera-glass, and without magnifying power, two tenths less than that star.
November 5	—In the light of the gibbous moon, it is equal to Alpha Piscium and less than Gamma Ceti.
November 11	—At even altitudes, it is equal to Delta Ceti, but viewed with opera-glass seems brighter.
November16	—Less than Delta. In opera-glass not fully equal.

V ORIONIS.

The light change of this telescopic star is from 8.4 to 12 magnitude and its period is about 266 days. A chart of its neighborhood may be found in POPULAR ASTRONOMY for October, 1905. By a typographical error the comparison star *h* on the chart is changed to *n* in the observations that accompany it.

The decline of a maximum was observed as follows:

1907 Dec. 28	—Between *f* and *h* and a magnitude brighter than *m*.
1908 Jan. 2	—Nearer to *h* than to *f*.
Jan. 4, 9	—The same.
Jan. 19, 22	—About midway between *h* and *m*.
Jan. 27, 28	—Nearer to *m* than to *h*.
Feb. 7	—Invisible.

W CASSIOPELÆ.

In POPULAR ASTRONOMY for April, 1908, a chart of this variable appeared, and the data of a maximum that occurred between the 12th and 23rd of September, 1907. The record now given indicates that its period is not far from one year.

1908 Aug. 24	—Brighter than *d*, equals *c*.
Aug. 29	—Between *c* and *a*.
Sept. 4	—Brighter than *d* or *c*, equals *a*.
Sept. 29	—Brighter than *d* or *c*, less than *a*.

Eleven observations distributed from Oct. 1st to Nov. 2d showed no change, but on Nov. 17th it had decreased to the magnitude of *d*.

T DRACONIS.

On account of its long period of 435 days, this star has been frequently looked for in vain, but at length, in 1905, on June 22 and 26, was seen when about half a magnitude fainter than the closely adjacent star of 10.5 magnitude. Again it was just discernible on June 9, 11 and 18, 1906; but from April 11 to June 9, 1907, and from June 12th to the 28th, 1908, it was looked

for repeatedly, but in a four inch lens was undiscernible. By means of the chart in POPULAR ASTRONOMY for February, 1897, its neighborhood may be found less than a degree northward from ξ in the head of the Dragon.

Charts for the observation of S Draconis and X Virginus may be found in the May number of POPULAR ASTRONOMY, 1894. The latter variable was of about 11th magnitude on the 8th, 13th and 16th of April, 1904, and on the 15th of May of the same year had risen to 10th magnitude. It is easily found somewhat less than a degree to the northwest of Omicron Virginis.

S Draconis was of nearly 8th magnitude in May, 1906, and a year later, in May, 1907, was about half a magnitude less.

R ANDROMEDA.

The light of this variable ranges from below 12th to 7th magnitude. A maximum was predicted for August 10th, and a few weeks of its decline was observed as follows:

1908 October 21, 24—Of 9 magnitude.
November 2, 11—About 9.5 magnitude.
November 19, —Of 10th magnitude.

It has the long period of 407 days. ROSE O'HALLORAN.
San Francisco, Nov. 18th, 1908.

GENERAL NOTES.

Size of the South Polar Cap of Mars, 1907. Bulletin No. 29 gave the size of the South Polar Cap of Mars during the earlier months of the opposition of 1907. The present Bulletin gathers all my results upon the size of the cap from the beginning to the end of the observations deduced from two hundred drawings made of it as a part of the whole disk between March 22 and November 13, 1907. When the cap had greatly shrunk I made also micrometric measures of its diameter.

The size of the cap at given dates was then obtained:

1. By measuring its depth on the drawings at the time, and reducing this to latitude from the ephemeris data;
2. By measuring its breadth in longitude;
3. From its latitudinal position with regard to the planet's known features.

Of the three methods the last seemed to yield the best results, and these are arranged below in tabular form. In the table the first column gives the Earthly date of observation; the second, the longitude on the planet observed; the third, the latitude on Mars to which the cap descended; the fourth, its width in Martian degrees; the fifth, its area in parts of a hemisphere. The double-headed arrows mark the several presentations, the single-headed ones the half points between; while to the right of columns four and five respectively are the differences in degrees and in area occupied by the cap between the points marked.

The table shows the quantitative history of the cap for nearly eight of our months, from about its maximum extent to an approach to its minimum.

SIZE SOUTH POLAR CAP (1907). FROM DRAWINGS.

⊣⊢ indicates centers of presentations.
⊣· indicates halfway between centers.

Date.		λ °		Lat. °	Width. °	Diff.	Area. In hemispheres.	Diff.
Mar	22	270		32				
Apr.	2	180		40	⊣⊢104.5		.388	
			1					
	9	90		39	101.0		.364	
	16	45		37				
	18	0		40	⊣· 98.5	6.0	.347	.041
	26	270		39	95 0		.324	
May	6	180		45	⊣⊢ 91.5	7.0	.302	.045
			2					
14 } 18 }	16	90		46	85.5		.266	
	20	45		45				
	24	0		47	⊣· 82.0	9.5	.245	.057
	31	270		51	79.5		.231	
June	12	180		52	⊣⊢ 75.5	6.5	.209	.036
			3					
	20	90		51	71.0		.186	
		45		50				
	30	0		55	⊣· 67.0	8.5	.166	.043
July	2	270		60	63.5		.150	
	14	180		60	⊣⊢ 61.0	6.0	.138	.028
			4					
	23	90		58	58.5		.128	
	28	45		56				
Aug.	1	0		60	⊣· 54.5	6.5	.111	.027
	7	270		65	50.5		.096	
	21	180		68	⊣⊢ 47.0	7.5	.083	.028
			5					
	30	90		66	43.5		.071	
Sept.	2	45		62				
	6	0		67	⊣· 35.0	12.0	.046	.037
	16	270		72	29.0		.032	
	27	180		85	⊣⊢ 24.0	11.0	.022	.024
			6					
Oct.	7	90		78	16.5		.010	
	10	45		75				
	13	0		77	⊣· 14.0	10.0	.008	.014
	19	270		87	13.0		.006	
	28	180		90	⊣⊢ 10.5	3.5	.004	.004
			7					
Nov.	9	90		80	7.5*		.002	
	13	45		76				
		0		82				

* By direct measurement.

Lowell Observatory, Bulletin No. 35
November, 1908.

PERCIVAL LOWELL.

Professor R. W. McFarland. From a private letter from our personal friend, Professor R. W. McFarland of Oxford, Ohio, we notice some things that make up an exceptionally noble record, as an educator, in the great state of Ohio. Think of a man teaching 49 years, and having retired for more than a score of years, and still having a mind as clear, and, apparently from letters, as active as ever, and one has an example of mental strength and endurance that very few octogenerians possess.

We wonder if it is fair to credit these sterling and lasting qualities to the healthful and invigorating studies of mathematics and astronomy, in both of which Professor McFarland is a well-known scholar of high rank?

Additional Note on the Calendar. The centesimal years which are divisible by 400, as 1600, 2000, etc., all begin on Saturday. The years 1700-2100, etc., which leave a remainder of 100, when divided by 400, always begin on Friday. When the remainder is 200, as in the case of 1800, 2200, etc., those years always begin on Wednesday. In case the remainder is 300, as in 1900, 2300, etc., those years begin on Monday. That is, the centesimal years begin on Saturday, Friday, Wednesday or Monday. They have not occurred, and never will occur on Tuesday, Thursday, or Sunday. These may seem curious facts, but they are true.

Oxford, Ohio. R. W. McFarland.

Professor Young's Early Spectroscopic Work.—Some weeks ago the Editor received the following letter from Mr. Parsons criticizing the paragraph on Professor Young's early spectroscopic work which Dr. Poor included in his biographical sketch printed in the April, 1908, number. After several delays we were able to call Dr. Poor's attention to the point in question, and to receive his reply. Though so long after the publication of the article in question, the letters will be of interest to our readers, and they are given in full.

New Hartford, Conn.,

Editor Popular Astronomy: In your April issue Dr. John M. Poor in his admirable paper on the late Professor Charles Augustus Young, says on page 225, "Upon returning to Dartmouth he began at once his investigations in spectroscopy * * *". This statement is somewhat misleading. It would be correct to say that he again took up his investigations in spectroscopy, for in my senior year at Western Reserve, Class '63, Professor Young gave us some most interesting lectures on the solar spectrum using the spectroscope, which had been purchased by the college for his investigations in this line as well as for class work and it was well-known that he was devoting his spare hours to this subject. I can not give the exact date of the purchase of the instrument but it was said in my college days that only one other college in the country had its equal at that time; and it was at least six years later that Dartmouth got its spectroscope. Western Reserve University, therefore, rather than Dartmouth, should have the credit of providing Professor Young with the equipment which made it possible for him to enter upon the line of investigation in which he later became so distinguished.

May I add a line to say that Professor Young was highly esteemed and loved by all his associates and pupils and his departure from Hudson (the last of December, 1866) was considered a severe loss to the college. He was a man of large attainments in a wide range of subjects and would have distinguished himself in any line of work in which he chose to labor. In my last year in the preparatory school we read with him Cicero's Orations against Cataline and the grade of instruction he gave us was in marked contrast with that to which we had been accustomed. With all his keenness in original investigations in science he had the teaching faculty in a high degree and his life work as a teacher was well chosen. W. C. Parsons.

Hanover, N. H., Sept, 11, 1908.

EDITOR POPULAR ASTRONOMY: In reply to Mr. W. C. Parsons' criticism of my article on the late Professor Charles Augustus Young I will say that I did not intentionally deprive Western Reserve University of credit for assistance rendered in furnishing Professor Young with spectroscopic apparatus. Until Mr. Parsons called attention to it I was quite in ignorance of Professor Young's interest in spectroscopic work while at Western Reserve and I find the same to be true of others who knew him longer and more intimately than I. As yet I have not located references to his spectroscopic work at Western Reserve in articles published by Professor Young. Files of such articles—perhaps incomplete—and personal conversations with him were the sources of information from which the original article in the *Dartmouth Bi-Monthly* was written in 1905—the later one in POPULAR ASTRONOMY being the earlier one with some additions to meet changed conditions, the omission of material of local interest only, and whatever corrections had been made by Professor Young after the original article appeared. I am therefore indebted to Mr. Parsons for the information, furnished by him, which quite naturally escaped me.

JOHN M. POOR.

Dartmouth College,

Note on "Is the Universe Infinite?" In POPULAR ASTRONOMY for August-September, 1908, page 435, Mr. Owen Ely considered the question "Is the universe infinite?" and arrived at the conclusion that it is not, by an ingenious process of reasoning. The writer would like to call attention to a fundamental error in the hypothesis upon which the article in question is based.

Mr. Ely considers first the tide-raising power of the Moon, using the well-known fact that in general our satellite attracts unequally points situated on opposite sides of the Earth. From this he reasons that the stars will do the same.* Hence he concludes, "if it is supposed . . . that the stars are infinite in number . . . each section or sphere of stars in space exercises an equal attraction for the Earth, each lessening the effect of gravity, there would be exerted on every particle of the Earth's mass an irresistible pull outward from the center of the Earth—weight would cease to exist and the attraction of the Sun and planets would be nil in comparison to the strength of that force. . . . Since gravity would no longer be effective in the Earth or any other body, it is probable that all compounds and masses in the universe would be torn apart and the indivisible particles strewn through space at equal distances from each other." Since this latter condition does not exist, he concludes that the universe is not infinite.

The difficulty here lies in the fact that it is not a question of how great may be a force acting on a particle in any given direction but what is the *resultant* of *all* the forces acting on this particle. Only if the resultants are different in direction or magnitude for any two particles will these separate. Suppose a sphere of any radius, say 100,000 light-years, described about the Earth as a center. Granting an equal distribution of matter in space, a condition implied in Mr. Ely's article, we have the conventional homogeneous spherical shell. This, as is well-known, exerts no gravitational effect upon any body in its in-

* This is true for any individual star but the effect is vanishingly small.

† The proof of this theorem was first given by Newton in the Principia. It can be found in many texts on astronomy or physics.

terior.† Spheres of continuously greater radii out to infinity would similarly be ineffective. Hence the resultant attraction on any point of the Earth by all the rest of the universe, neglecting for the moment the bodies in the solar system, would be zero and there would be no force to tear the Earth asunder. The article under discussion, therefore, cannot be considered as containing any new proof against an infinite universe.

Mt. Hamilton, November 6, 1908. E. A. FATH.

The Brightness of the Stars as a Key to their Constitution and Changes. Mr. Parkhurst's address was illustrated by lantern slides from photographs taken at the Yerkes Observatory. He introduced the subject by three views of Morehouse's comet, taken by Barnard 1908 Sept. 20, 23 and 26, calling attention to the remarkable changes taking place in the tail. Tracing the cause of this activity back to the Sun, views were shown of the entire disk, both direct and spectrographic, also views illustrating the development of a spot and the rotation of the Sun, May 6-13, 1907. These were followed by four views showing the development of a remarkable eruptive prominence May 21, 1907 in which the prominence increased from a height of 130,000 to 230,000 miles in one and a half hours.

The changes in the stars, which cannot be so completely observed, were illustrated by photometric slides from negatives taken with the 2-foot reflector and the 6-inch extra-focal camera. Reflector photographs of the long period variable star *V Delphini* showed the variable at the tenth magnitude 1902 Sept. 7, and sixteenth 1904 Aug 6. Light changes in Algol-type variables, caused by eclipses, were illustrated by a photograph of the variable *U Cephei*, taken 1904 June 25, containing twenty successive exposures within an interval of six hours, showing the gradual decline, the minimum and the increase to normal light. Diagrams of the light-curve, the radial velocity-curve determined from spectrograms, and the orbit of Algol, showed how completely the eclipse theory accounts for the observed phenomena.

The photography of star-colors and color-changes was illustrated by slides of the red variable star *U Cygni*, taken within a few minutes of each other with and without a color-filter, and the former showing the red star at its visual brightness, and the latter showing it five magnitudes fainter. Simultaneous light-curves of the short-period variable *Y Cygni*, from photographs made with and without the light-filter, showed that the visual range in brightness was 0.85 magnitudes and the photographic range 1.50 magnitudes; a possible explanation of the cause being the greater absorption of the blue rays in the star's atmosphere at minimum.

Reference was made to the bearing these changes may have on the problems of stellar evolution.

As a contrast to these active bodies on which such varied changes are taking place, slides of the dead planet, the Moon, were shown.

(Address given at the dedication of the Alumni Observatory of Wheaton College, Oct. 1, 1908.)

Comet 1890 VII Spitaler.—The computation of the course of this periodic comet at its next return has been undertaken by Cr. Fr. Hoffer, Assistant in the Observatory at Triest.